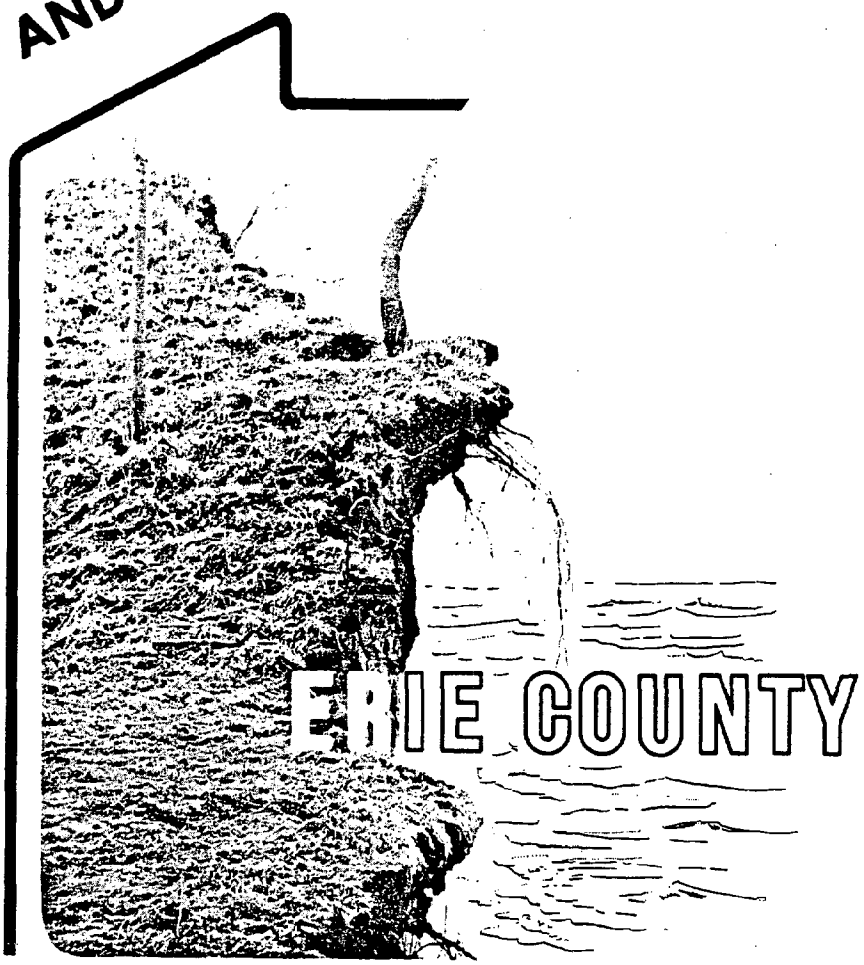
Pennsylvania Coastal Zone Management Program

SHORELINE EROSION AND FLOODING



ERIE COUNTY

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF RESOURCES MANAGEMENT

COMMONWEALTH OF PENNSYLVANIA

Milton J. Shapp, Governor

DEPARTMENT OF ENVIRONMENTAL RESOURCES

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Office of Resources Management

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SHORELINE EROSION AND FLOODING, ERIE COUNTY

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Prepared by

THE GREAT LAKES RESEARCH INSTITUTE

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ABSTRACT

Due to higher than normal water levels in the Great Lakes Basin since 1972, there has been accelerated shoreline erosion and bluff recession. As part of the Coastal Zone Management Program in Pennsylvania, a study of the Erie County shoreline was made between January and June, 1975.

Erie County contains approximately 48 miles of lakeshore and five miles of bayshore. The recession analysis primarily focused on 40 miles of lakeshore excluding Presque Isle Peninsula.

The main purpose of the study was to identify and classify hazard areas on the lakeshore. There were 109 areas (residential sections, cottage areas, camps, parks, industrial sites, etc.) classified as critical, moderate, or limited hazard areas. There are 44 critical hazard areas, 51 moderate hazard areas, and 10 limited hazard areas.

The most critical areas are in Springfield, Millcreek, and North East Townships. The townships of Girard, Fairview, and Harborcreek are somewhat less hazardous, but are still subject to significant damage within 25 years. The City of Erie and Lawrence Park Township have the least degree of hazard due to the protection offered by Presque Isle Peninsula.

The most immediate threat on the lakeshore is flooding and erosion in low-lying cottage areas. There have already been over two dozen cottages completely destroyed and over 100 cottages that have suffered damage. The rate of recession of the bluff has increased significantly along the entire shoreline during the past three years, and if the current rates continue over the next 25 years, several hundred homes and cottages will be endangered. The bluffs in the Millcreek and Erie bayshore are relatively stable. The principal hazard in the bayshore is flooding of low-lying dock areas.

Average recession rates since 1938 were measured from aerial photographs at 89 points throughout the county. The average long-term rate for the points measured was calculated to be approximately one foot per year. The bluffs west of Presque Isle have a rate slightly higher than the average. The bluffs east of Presque Isle have a rate slightly lower than the average due not only to the protection offered by Presque Isle, but also to the existence of long stretches of exposed bedrock above water. The actual rates measured at the points varied between two inches per year and 52 inches per year in the west county and between two inches per year and 21 inches per year in the east county. However, because of the great variety of usage and protection at different points on the bluff and because of the many complex causes of recession, the recession rates are not constant over time and do in fact vary at each location, depending on the level of lake water and climate variations.

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SECTION 1
PURPOSE OF STUDY

Since 1972 high lake levels have brought on a new wave of concern in the Great Lakes Basin for shore property and structures within the erosion and flood prone sections of coastline. The concern is addressed in Federal legislation through the Coastal Zone Management Act of 1972 which has mandated research into coastal processes and the function of the nation's coastal areas. Within the Commonwealth, the Lake Erie shoreline has come under extensive attack during this time period. Property owners with land adjacent to the shore are losing as much as three feet per year of bluff. Those with structures within a recession limit of ten years are especially concerned as are those with beachfront structures susceptible to destruction by every storm.

It is the intent of this study to identify areas of the coastline that are considered hazard areas under the following guidelines:

1) Those properties, or structures, that are in danger of being destroyed by a receding bluff.

2) Those properties, or structures, that are in danger of being destroyed by floodwaters created by combinations of storm and highwater level.

3) Each hazard zone will be assessed as to whether the threat to structures is imminent (critical); or those potentially hazardous by the year 2000 (Moderate), and those areas that are relatively secure from threat within the next 25 years (limited).

NEED FOR STUDY

Interest in shoreline changes due to erosion and recession phenomena is apparent at all levels of government. Federal, State and local units are under various pressures to identify the seriousness of the threat and to plan for the future of the coastal zone. Within the Federal structure, the Army Corps of Engineers has for years been responsible for monitoring change in coastal areas. According to a representative from the Corps, "... the problem of shore damage, both from erosion and flooding, demands high quality technical studies to support non-structural shore damage reduction strategies."[1] He adds, "From my perspective, there is no comprehensive or coordinated Federal program available at the present time for the recession or erosion rate analysis on the Great Lakes."[2]

There are various agencies involved, however, mostly at the planning stage, for some type of recession and erosion rate analysis. The Corps has completed 22 studies under the cooperative beach erosion control program and 29 studies under the mandate of the River and Harbor Act (1972). The Department of Commerce (NOAA) has been given the responsibility for carrying out the Coastal Zone Management Act (1972). With this act, each state will institute research with the ultimate goal of providing information to local planners for the protection of future land owners in the coastal zone.

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[1] Recession Rate Workshop Proceedings. R. Buddecke, p. 6.

[2] Ibid. p. 5.

The Natural Disaster Assistance Act (1973) will require a tremendous amount of information about flooding and recession or erosion so that programs for compensation for structural loss can be established with uniform guidelines.

Other Federal agencies have funded research related to coastal phenomena including the Department of Interior (OWRR), Department of Commerce through the Sea Grant Program and the Department of Defense, Coastal Engineering Research Center. The Environmental Protection Agency is also in need of information relative to the effect of erosion on the quality of water in the Great Lakes.

State agencies in the Great Lakes Basin have essentially the same requirement, but are under greater pressure to establish information in support of enacted legislation that will establish setback requirements, zoning changes and activity designation. It is imperative, then, that each state develop enough data on respective coasts to accomplish the goals of the various programs.

With this report, the Commonwealth will have information that will meet the immediate needs as seen by the agencies involved. Within the recommendations for future study presented in this report is an identification of further projects to substantiate the intital steps made here.

AUTHORITY AND SCOPE

The work was undertaken through contract with the Pennsylvania Department of Environmental Resources, the administrators of the Coastal Zone Management Program for the Commonwealth, under the provisions as set forth by the National Oceanic and Atmospheric Administration (NOAA), and within the authority of the Coastal Zone Management Act of 1972.

The scope of work includes the following elements:

> "Establish Erie County Shoreline physiography, particularly bluff characteristics; define and evaluate the coastline as a hazard zone in relation to both recession and erosion-related phenomena, including an examination of causative factors (both environmental and man-made); define, inventory and locate all hazard areas in which recession or erosion has caused, or may potentially cause, damage to land or structures; develop estimated coastal recession rates based on historical evidence and project future recession-prone hazard areas."

SECTION 2
AREA OF STUDY

General

The area under examination is that section of the Southern Shore of Lake Erie under the political identification of Erie County, Commonwealth of Pennsylvania and the minor civil divisions that border on the shoreline (Figures 1 and 2). In particular, the study comprises that section of the shore interface described as that area between the zone of breaking waves shoreward to the 100 year recession limit as delineated within the study. The critical physical features included are the beach face, the bluff (toe, slope, and crest), that area behind the bluff and affected by potential recession comprised of flat-lying glacial sands and clays, and the minor delta areas associated with the streams that cut the bluff.

General Physical Description of Study Area

The coastline of Erie County, Pennsylvania consists essentially of bluffs of varying heights above mean lake level (571 feet) from ten to 170 feet. Breaks occur in the bluffline where streams have established drainage channels from the area behind the coastal zone. Depending on the size of the stream, embayments have been developed varying in size with the amount of sediment being carried by the stream, the volume of outflow, and the strength of the longshore transport system which tends to form baymouth bars protecting the bays and which carries the stream load down shore. Weather tributaries have also added an irregularity to the coastal face dissecting the bluffs into a series of gullies of various depth and breadth. Induced gullies have formed as a result of agricultural tile drains, septic tank outfall, and other forms of drainage.

In the central county, a unique sandspit peninsula protects a large harbor at Erie. Over 3,500 acres in size, Presque Isle Peninsula is made up of beach and dune deposits that alternate with lagoons closed as formation of the spit progressed. The narrow neck is attached to the shoreline on the west and an artificial channel has been maintained at the eastern and western basins of Lake Erie (Figure 3) and the system is now dependent on longshore transport for sediment required for maintenance. The maximum elevation of the spit is just over ten feet, the relief being produced by sequential dune development through succession. The bulk of the spit is particularly susceptible to damage by erosion, littoral currents, and flooding. A massive amount of data has been accumulated by the Army Corps of Engineers as a result of Cooperative Beach Erosion Control Studies. Therefore, Presque Isle has been eliminated from this report to avoid needless redundancy in effort. The studies have been referenced in the bibliography.

The inner bay shoreline protected by Presque Isle was included in this study. However, because of the protection offered against attack by lake waters, the high density development of the shore with resultant interior and exterior drainage control, and the stability of the bluffs in that area, a complete recession analysis was not performed for the bay shore area. Most of the shore is protected, indirectly, by control structures established for some other purpose, particularly dock facilities and materials storage areas. Examination of the bayshore bluff revealed bluffs varying in height from 20 to 90 feet with a stable vegetative cover in most areas.

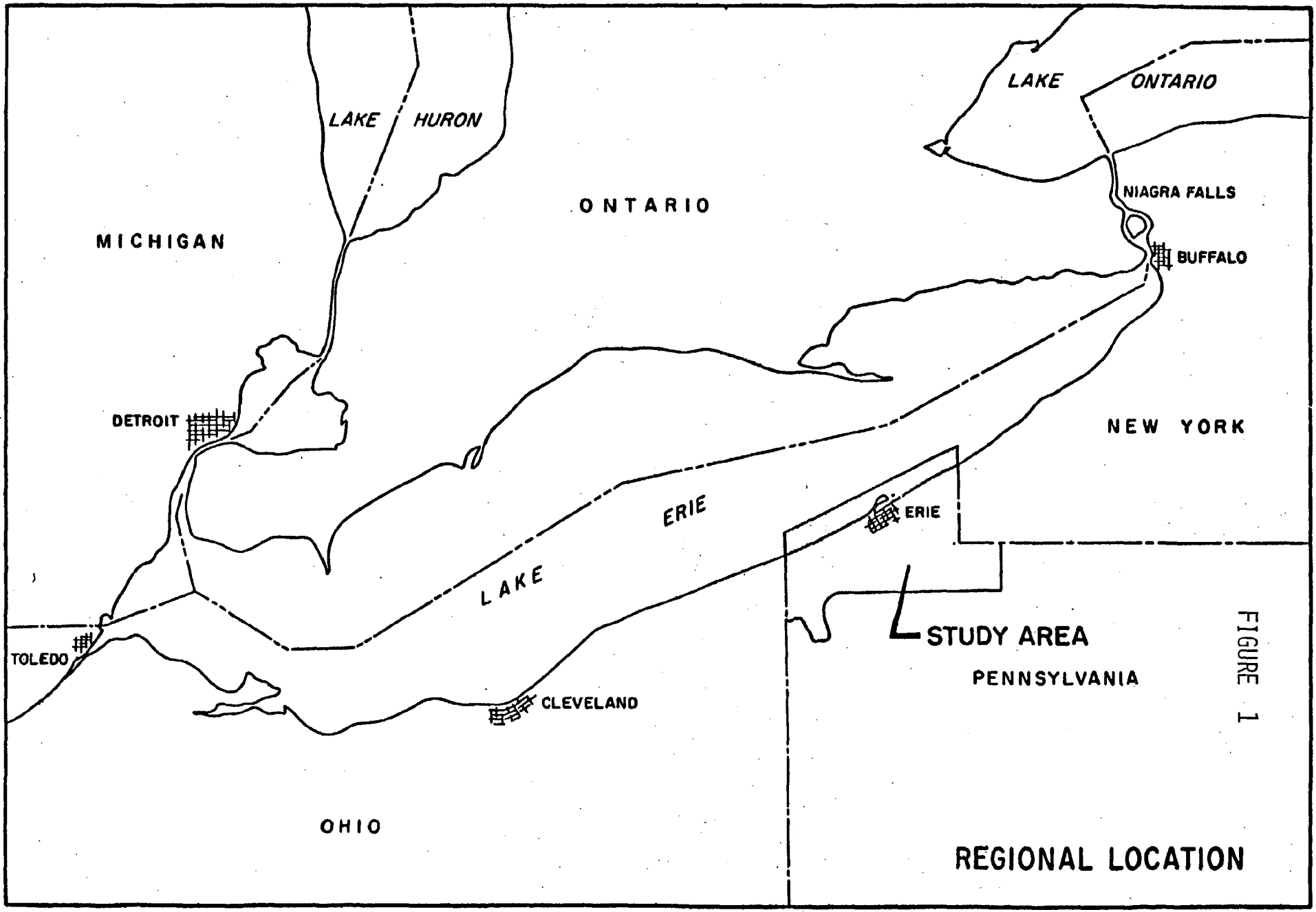


FIGURE 1

Source - ENGINEERING-SCIENCE, INC.

FIGURE 2

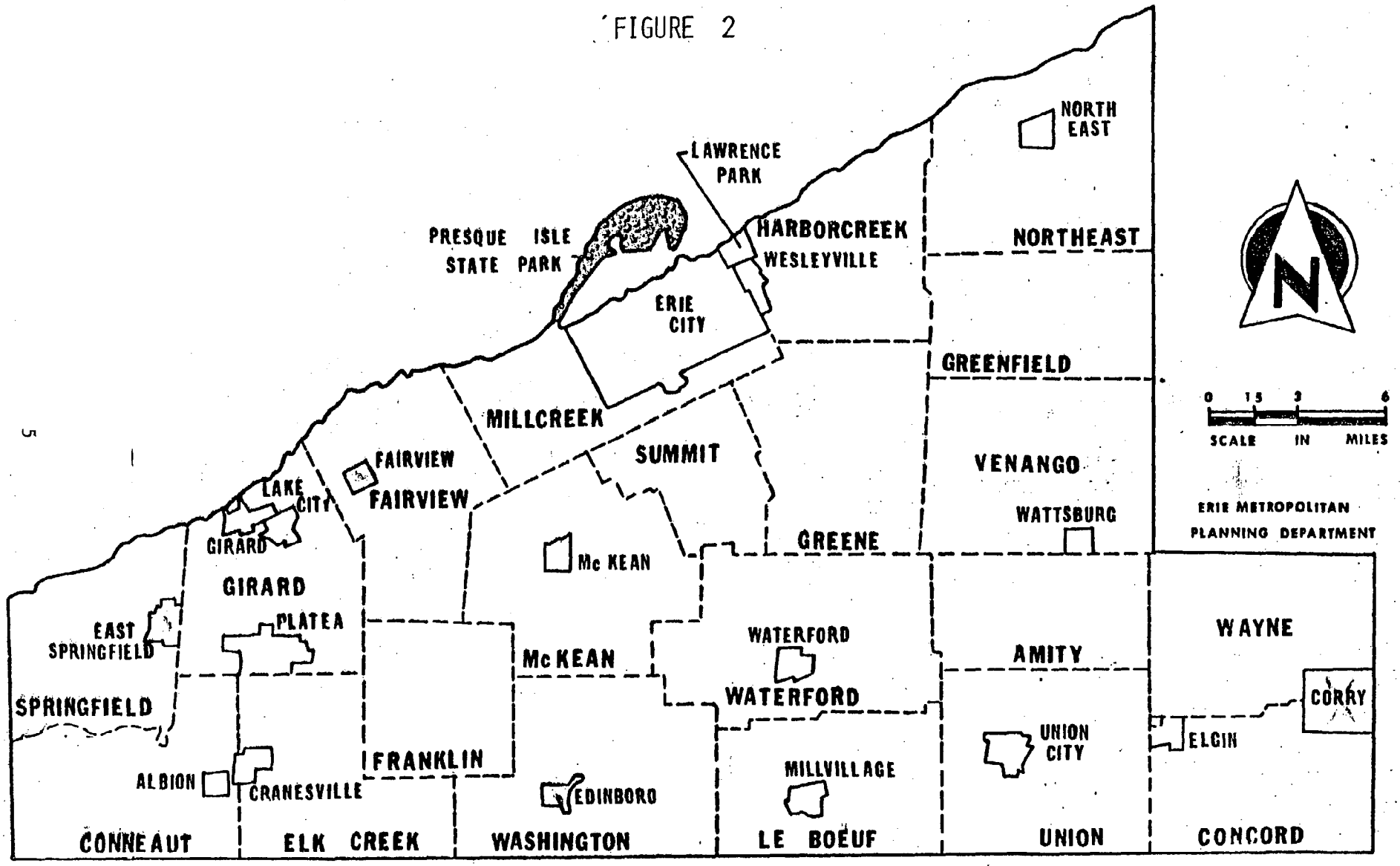
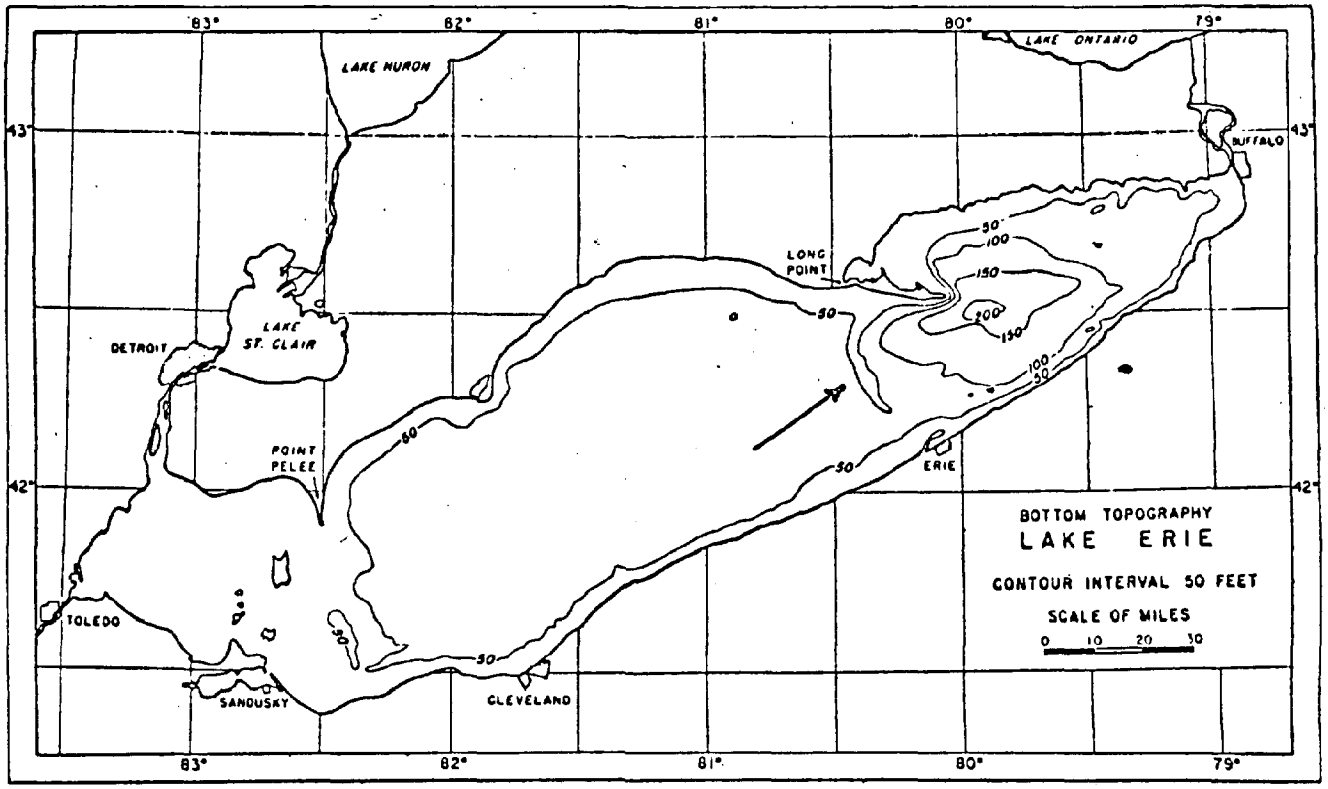

NORTH EAST
LAWRENCE PARK
PRESQUE ISLE STATE PARK
HARBORCREEK
WESLEYVILLE
NORTHEAST
ERIE CITY
GREENFIELD
MILLCREEK
SUMMIT
VENANGO
FAIRVIEW
LAKE CITY
FAIRVIEW
WATTSBURG
GIRARD
GREENE
Mc KEAN
GIRARD
EAST SPRINGFIELD
PLATEA
WAYNE
WATERFORD
McKEAN
AMITY
SPRINGFIELD
WATERFORD
CORRY
UNION CITY
ELGIN
ALBION
CRANESVILLE
FRANKLIN
MILLVILLAGE
EDINBORO
CONNEAUT
ELK CREEK
WASHINGTON
LE BOEUF
UNION
CONCORD
0 1.5 3 6
SCALE IN MILES
ERIE METROPOLITAN PLANNING DEPARTMENT

FIGURE 3



The bottom topography of Lake Erie.

Source: after Hough, Great Lakes Basin

→ indicates moraine deposits separating the east and west basin and suspected to have provided the source material for both Presque Isle and Long Point, Canada

The following is a general summary of the use of the bluff in each township or municipality on the shoreline:

Springfield Township - six major cottage areas, four private summer camps, a county park, a township beach, an undeveloped industrial site (Penelec), and a small number of permanent residences.

Girard Township - an undeveloped industrial site (Penelec), the mouth of Elk Creek, three cottage areas, three private summer camps, a community park, a fruit farm, and a few permanent residential areas, including several high value homes. Also Lake City Borough has two separate shoreline areas within the township; one, a small combined summer/permanent residential area, and the other having a concrete works plant.

Fairview Township - medium to high value permanent residences in approximately nine separate areas. There are also a few small cottage areas, a summer camp, a private country club, and the Walnut Creek Fish Commission Access Area.

Millcreek Township - one high value permanent residential area, a large undeveloped private estate tract, seven beach cottage areas and a restaurant. On the bluff above the cottage areas, there are four medium-value residential areas, a mobile home park, and a public amusement park. Also, the only land access to Presque Isle State Park and the U.S. Coast Guard station is in Millcreek Township. The Millcreek bayshore contains a mobile home park, an outdoor theater, an apartment complex, a new county park, a City of Erie water pumping station, and a high value residential area.

The City of Erie lakeshore - two large manufacturing facilities, a small oil tank farm, a public boat launching ramp, a series of two dozen private boat houses built on public land, a private cemetery, a medium value permanent residential area, and a private facility available for parties and receptions. It is also the site of the diked disposal area proposed by the Army Corps of Engineers to hold Erie Harbor dredging material.

Lawrence Park Township - a medium value residential area, a township boat launching facility, a private fishing boat facility, and a private golf course.

Harborcreek Township - ten medium value residential areas, four cottage areas, a small oil tank farm, a church property, an elderly housing facility, a private camp, a county park, three small motels, and a public tavern.

North East Township - approximately ten medium value residential areas, five cottage areas, a private yacht club, a township beach, a boat livery, the Dewey Road Fish Commission Access Area, a home for the elderly, and several fruit farms.

SECTION 3
CONTRIBUTORY PHYSICAL PROCESSES

> Shoreline recession, which is a geometric concept, involves the landward displacement of shore or bluff lines; erosion is a mass concept, involving the net removal of material. Recession, which is what the trained and untrained first observe, is not as fundamental a term as is erosion.
>
> The consideration of shore processes in terms of energy, material, and geometry demonstrate the importance of interaction between factors and groups of factors contributing to recession and erosion. The proposition that the operation of a single factor accounts uniquely for an erosional or recessional event is at best an oversimplification.*

The purpose of this section is to provide the foundation upon which the Erie County recession rate analysis and critical hazard area identification was accomplished. It must be emphasized that examination of the scientific processes involved in the coastal zone is one of the most important areas of study for future determination of shoreline use.

MASS WASTING PRINCIPLES

All of the factors discussed later in this section relate to the mass wasting and subsequent erosion of material forming the bluff. Since mass wasting on the bluff is the direct result of these factors working singly or in concert, a brief description of principles is offered.

Any changes in the form of a bluff will be due to the normal elements of landform change, principally: structure, process and time. The form of any slope is determined by the relationship between the rate of decay of the underlying material and the rate of removal of the debris produced from the surface and the base of the bluff. The forces described below work on the slope itself or at the base or crest of the bluff in molding its form. The nominal angle of a slope is generally governed by the rate of removal of material at the base. When debris piles up at the foot of a slope it means that production exceeds removal and such a slope will be less steep than the one from which material has been removed.

The types of movement evident on the bluffs in Erie County include falls produced by undercutting material on slope or sod at crest, slides in the form of rotational slumps, and flows produced by super-saturation of clay materials. Distinctive scars and depositional features produced by slides and flows are apparent in most sections of coastline. Especially common are spoon-shaped scars associated with shear failure along arcuate planes. The hummocky features at the base of the bluffs are characteristic in landslide topography.

A landslide will be set in motion when the stress along the potential surface of rupture exceeds the resistance to shear along that surface. The

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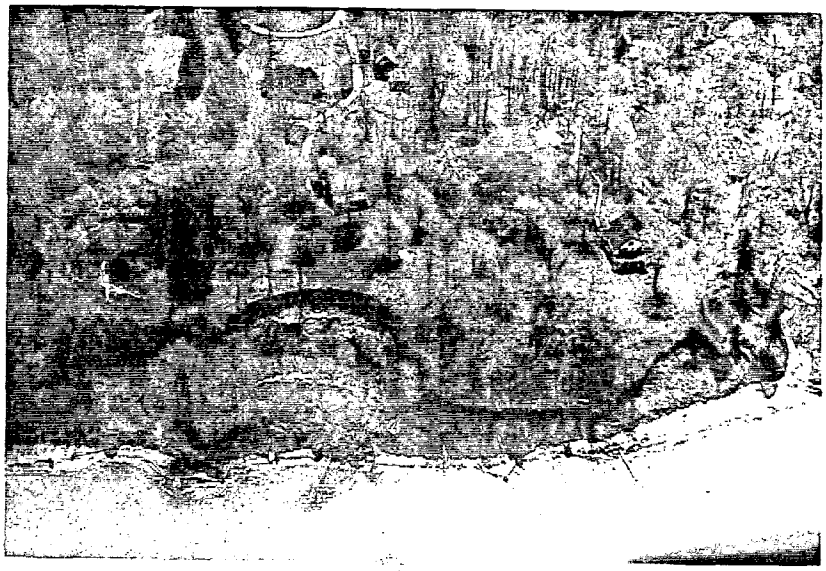
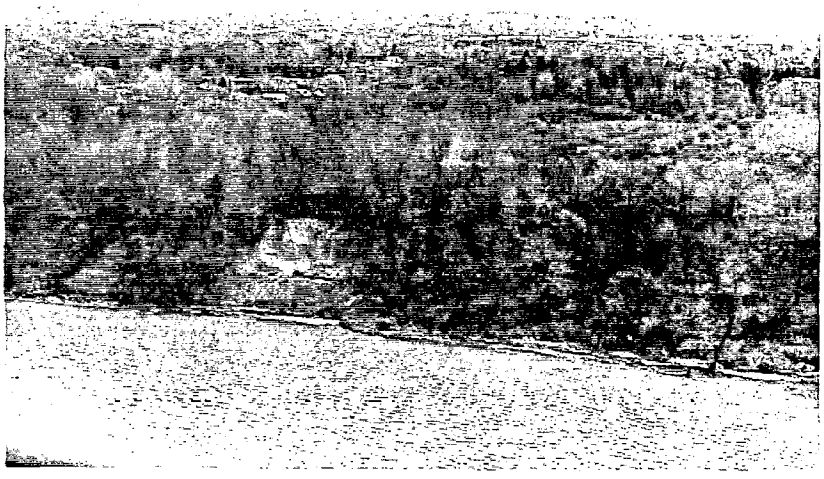
*Pincus, "Recession of Great Lakes Shorelines," Great Lakes Basin, 1962, p. 123.



Above and below: Cirque-like features produced by landslides in weakened materials.



following conditions usually are causative factors:

a. Increased weight of overlying material due to absorption of water

b. Decrease in mass resistance due to undercutting

c. Decrease in shear strength of the material itself due to the absorption of moisture.

One example of change would be a rise in water table, forcing more water into the bluff face and reducing shear strength. We have found this to be one of the principle causes of recession on the bluffs of Erie County.

Mass wasting occurs on a bluff when any of the conditions below are met:

1. Deep weathering

2. Sedimentary structures of variable lithology

3. Swelling in clays

4. Large quantities of water

5. Seasonal ice formations

6. Undercutting by wave action

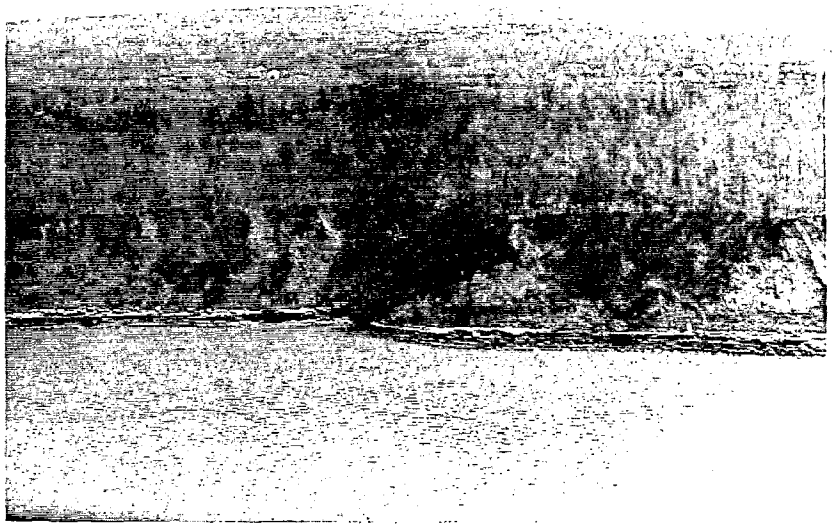
Unfortunately for the shoreline user, all of the above factors are active in the coastal zone. It is unreasonable to expect that individual efforts to retard mass wasting by the placement of debris or rip rap of some kind will have much success.

The following are factors that are generally accepted by researchers to be most critical as contributory elements in recession and erosion of shoreline areas:

1. Lake water levels
2. Storm conditions and frequency (waves, storm surge, changes in profiles of equilibrium)
3. Geological structure of the bluff and beach area
4. Wind direction and strength
5. Material availability in longshore transport systems
6. Ground water seepage
7. Sheet runoff on bluff face
8. Runoff from area behind bluff crest
9. Frost action and raindrop impact
10. Induced drainage onto bluff face related to man's activities
11. Ice conditions on lake
12. Control structures in shore zone
13. Vegetation on crest and slope
14. Land use
15. Sediment loading by streams
16. Stream dissection (valley widening and headward erosion)
17. Beach deposits at base of bluff
18. Gravity

Each of the above will be briefly explained as to effect and degree of threat.

Above: An area of slumping due probably to increased infiltration of ground water because to vegetation cover at crest



Above: Typical hummocky appearance produced by landslide activity

LAKE LEVELS:

The factors producing high water levels on Lake Erie over the past three years include abnormal amounts of precipitation in the basin over this time period, less evaporation from surface of the lake, and the condition of ground water supply already present during periods of heavy precipitation. Precipitation in the spring and fall as well as snow melt all contribute generally to runoff as opposed to infiltration, producing a problem of excess runoff during these periods. Lake levels can be expected to vary as the elements producing them vary. As a result, water level reaches a high on the lakes in mid-summer and a seasonal low during the winter months. Variation within the elements over extended periods of time will produce period highs and lows over time. However, there is no scientific evidence that short term cycles (seven of 11 years) are a factor in water levels. The variables have been such that, in combination, they have produced record high water levels on Lake Erie from 1972 to the present. The recorded high (573.5 ft.) during the summer of 1973 was as much as three feet over average level (570.4 ft.) for the period of record (1960-1973) and five feet over low water datum (568.6 ft.).

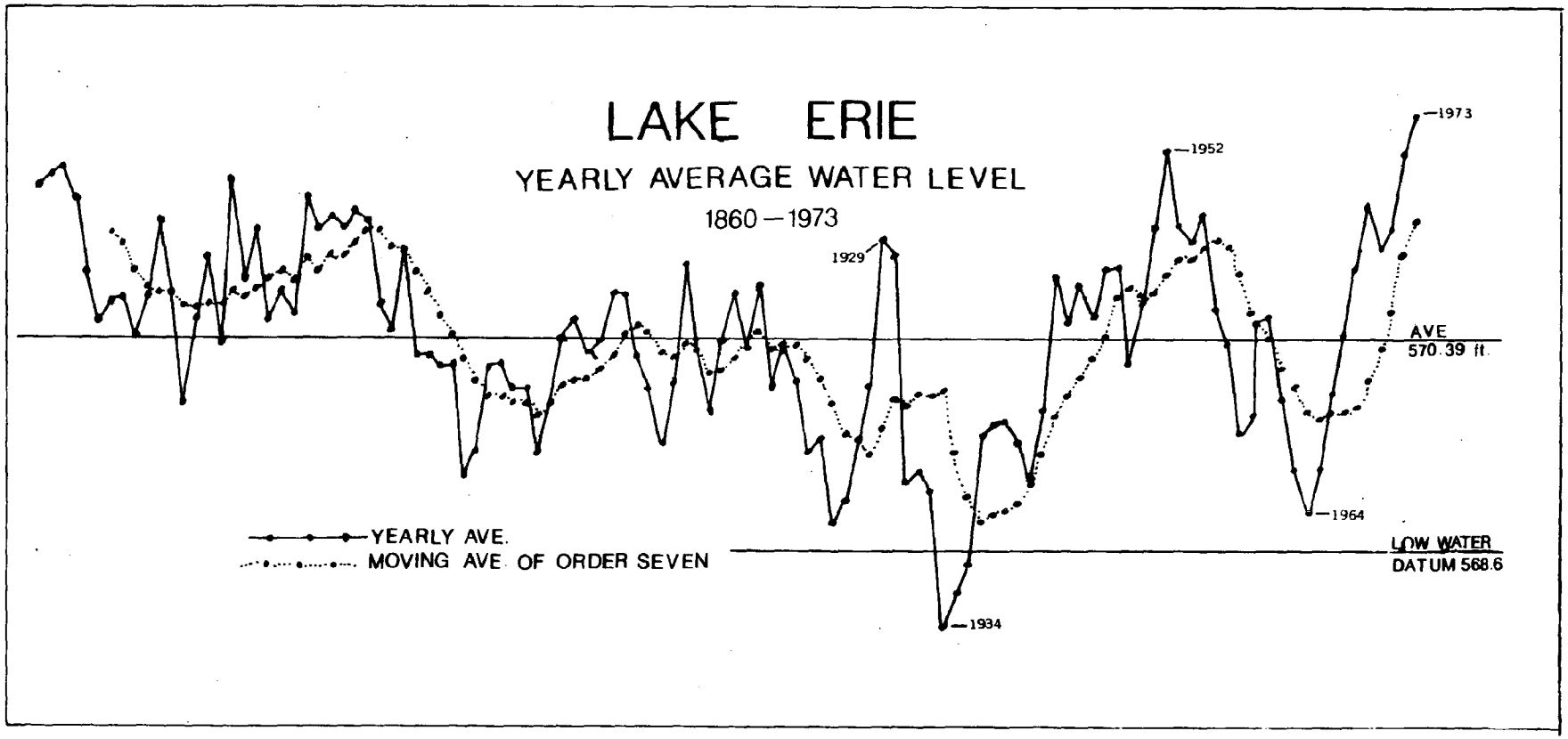
The hydrograph for the period of record is reproduced in the appendix (Appendix B) to allow an examination of water level variability in relation to periods of development in the Erie County coastal zone from a historical perspective.

Figure 4 is an analysis of the period of record, averaging monthly data over that period and applying a smoothing line provided by computing a moving average of order seven. The result clearly indicates that the water levels now being experienced are well above average for the period of record. During the mid-1950's there was a brief period of high water, but essentially water levels (until now) have not been significantly above the average for any length of time since before 1900. However, most of the construction in the coastal zone has taken place since 1900 (i.e., during low water periods). As a result, property owners have developed expectations regarding water levels that may not be applicable in the future. Future planning must involve an understanding of this phenomenon to protect future investment.

EFFECTS OF HIGH WATER LEVEL:

Figures 5, 6, and 7 illustrate the relationships of water level with conditions in the coastal zone. As Figure 5 illustrates, structures built behind protective beach berms, but in effect lower than high stage levels, will be flooded during periods of high lake levels. Storms producing waves of even moderate height will produce greater severity in terms of damage. These areas are susceptible to damage even at normal water levels during time of storm as a result of wind set-up over a long fetch producing wave uprush. Figure 6 shows the effect of storms on water levels. This tilting (seiche) effectively drowns narrow beach areas that have low sloping profiles and creates a zone of breaking waves higher on the beach face during high water levels causing damage to shore structures previously protected by beach deposits. In the West County, this effect caused the destruction and severe damage to cottages in the Baer Beach and Eaglehurst sections. In the East County, the effect was duplicated in the Francroft-Woodmere area. Ironically if water levels subside in the lake these areas will once more have broad sandy beaches. Future construction in these areas should take into consideration that any lowering or subsidence of lake levels could be temporary.

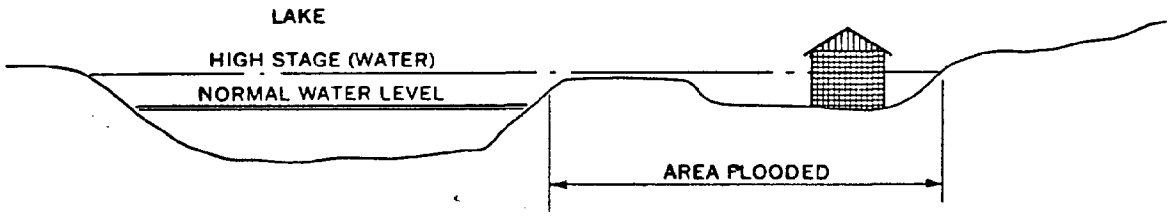
FIGURE 4



Source: Paul Knuth

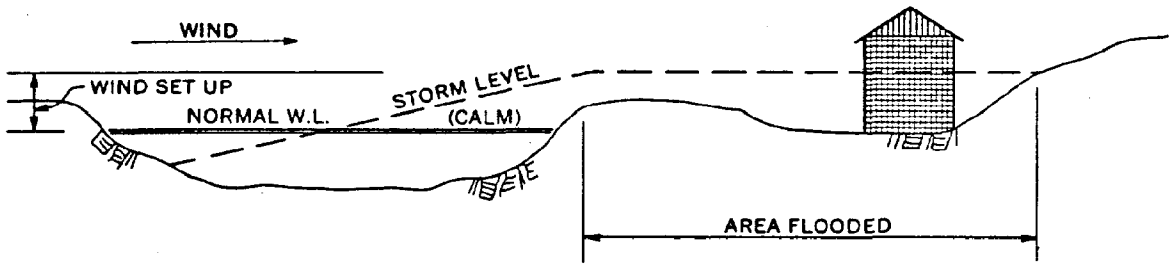
FIGURE 5

A. FLOODING DUE TO HIGH, CALM WATER STAGES (MEAN MONTHLY)



CALM WATER LEVEL BELOW LAND CREST. HIGH WATER EXCEEDS LAND HEIGHT.

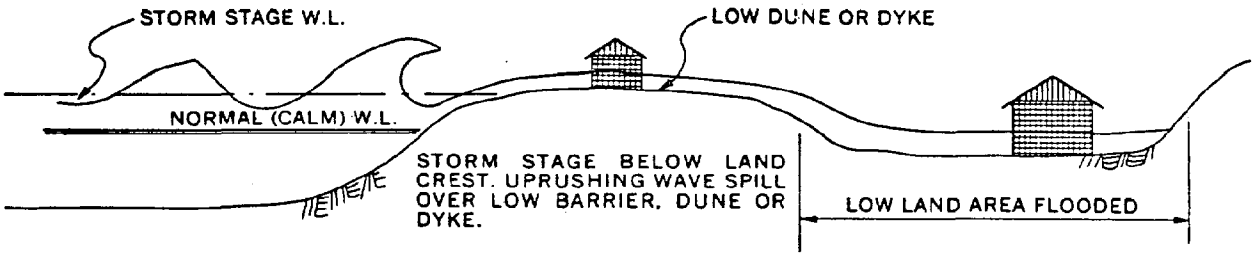
B. STORM STAGE FLOODING



CALM WATER LEVEL BELOW LAND CREST. STORM WATER LEVEL EXCEEDS LAND HEIGHT.

THE PRINCIPAL DIFFERENCE BETWEEN A & B IS THE DURATION. IN A., THE DURATION MAY BE ONE TO SEVERAL MONTHS. IN B., THE DURATION IS USUALLY ONLY SEVERAL HOURS, ALTHOUGH IT MAY REMAIN LONGER, DEPENDING ON DRAINAGE BACK INTO LAKE.

C. WAVE UPRUSH FLOODING



USUALLY OF SHORT DURATION AND LOW WATER COVER IN AREA FLOODED.
AMOUNT OF FLOODING DEPENDS ON STORM SEVERITY AND DURATION

TYPES OF FLOODING.

Source: Great Lakes Water Levels Board

FIGURE 6

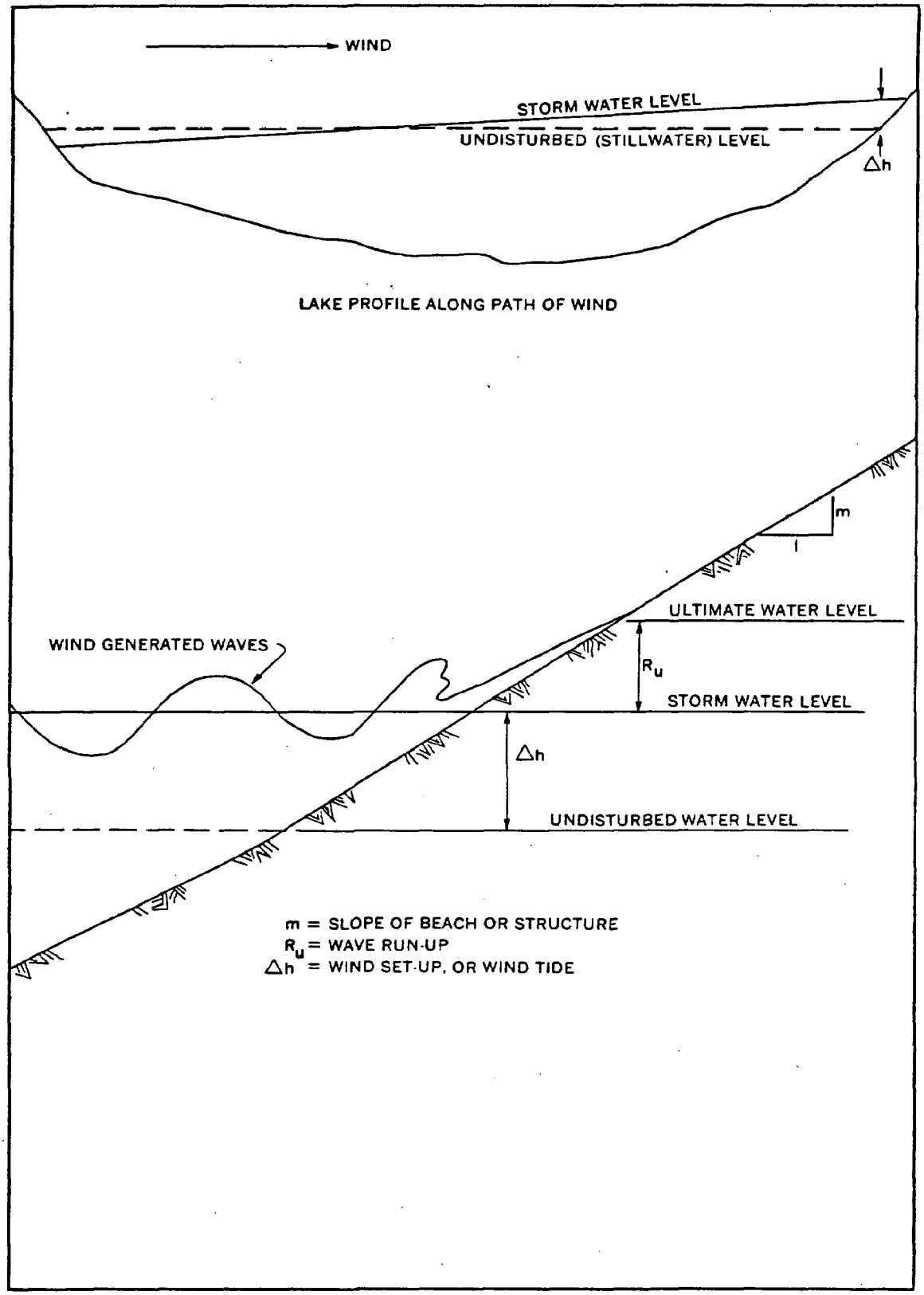
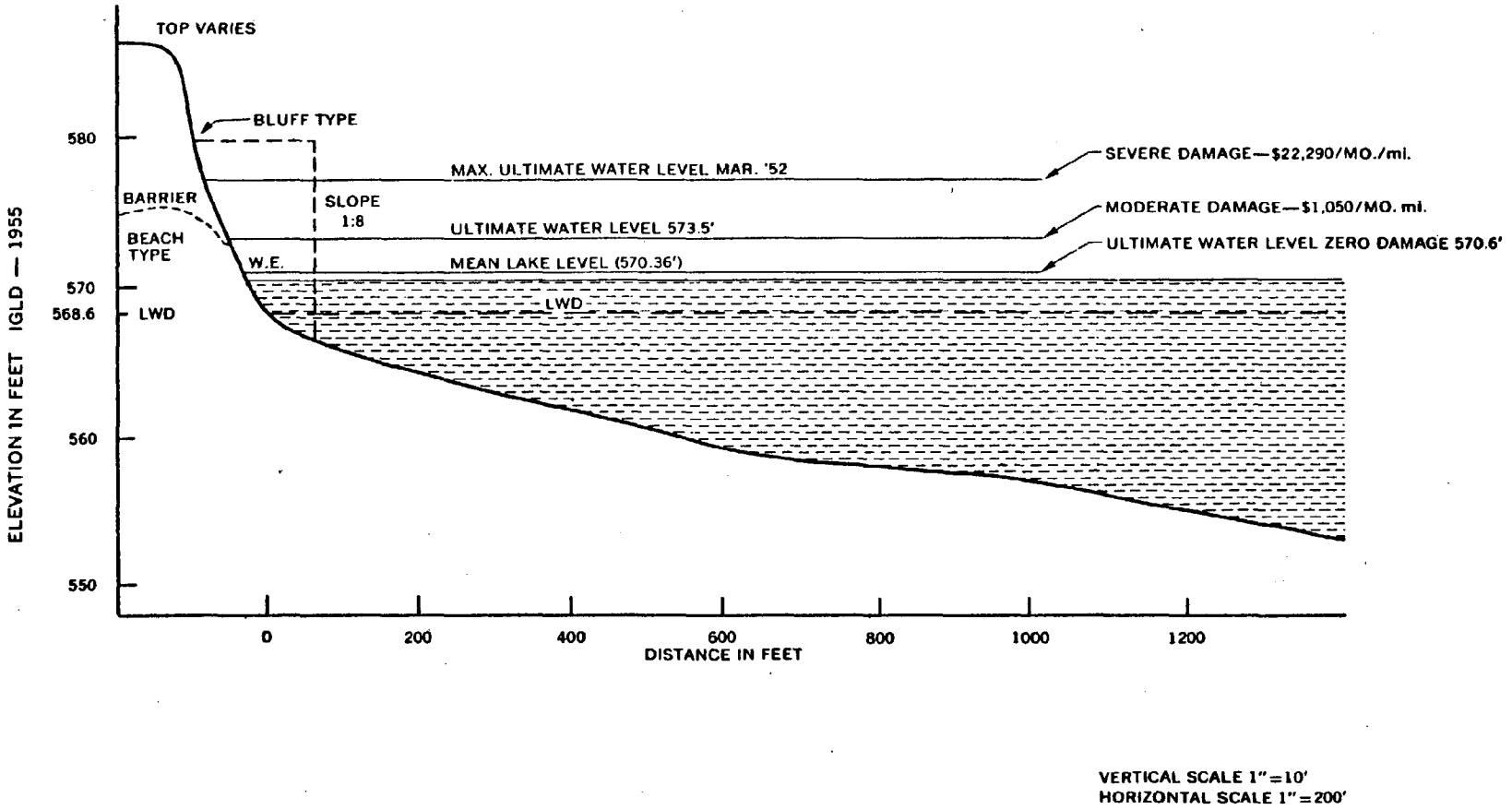


DIAGRAM OF STORM EFFECTS ON WATER LEVELS.

Source: Great Lakes Water Levels Board

FIGURE 7

LAKE ERIE PROFILE (TYPICAL SHORE)



LAKE ERIE PROFILE

Source: Great Lakes Water Levels Board

SPECIAL NOTE:

As a result of contact with and response from citizens during this project, the following observations seem pertinent:

Most citizens do not understand the complex factors that affect water levels in the Great Lakes. Furthermore, citizens in general seem to think that the level of Lake Erie can be closely controlled by means of "dams at Niagara Falls." Despite periodic articles in the local newspapers on the subject, there still exists a need for better public understanding of the complex factors involved.

WAVES AS A FACTOR IN EROSION AND RECESSION:

Essentially two types of waves can be identified as being active in this area. Figure 9 illustrates shore zone and wave characteristics. The first type is constructive waves in which the backwash is relatively weak and that will result, after a long period, in the building up of a beach with a broad berm of various material sizes. The berm usually has a more or less steep front leading down to the more gently graded profile of the foreshore. Where beach accumulations have survived, the berm usually consists of coarse materials up to cobble size or flags depending on location, as well as a jumble of debris carried by the transport system and deposited on the berm during storms. Because of the accelerated rate of recession of the bluffs, trees have become a common depositional feature of the entire beach. In many cases, downed trees have fastened themselves to the shore and have acted as natural groins and seawall structures and have offered some measure of protection to the berm.

The second type of wave is of the destructive variety in which the backwash is quite strong. As a result, scouring of the beach face takes place and materials move outward, reducing the extent of the beach significantly, in fact to "zero" in many cases. If waves with destructive tendencies prevail for any length of time, then erosion of the base of the bluff will take place.

STORM SURGE:

When high lake levels are combined with wind and storm waves, the result is storm surge. Low lying and easily erodible coasts are especially vulnerable to these disastrous coincidences.

CONCEPT OF PROFILE OF EQUILIBRIUM:

Figure 9 illustrates the concept of the ideal profile of equilibrium and is the result of conditions prevailing with respect to water levels and storm activity. Line AB represents the slope involved. If AB represents the steep bluff conditions prevalent in the Erie shoreline, the result is erosion at the base producing steepening of bluff slope. If the material involved is easily erodible, it is carried to just off-shore or moved by longshore transport. If water level is lowered and storms are moderate, the shallower slopes of beach formation are exposed and greater amounts of deposition will occur. Therefore, bluffs with a bedrock exposure can be expected to have little accumulation of materials at their base, even under optimum conditions, except that which might be provided by longshore transport.

FIGURE 8

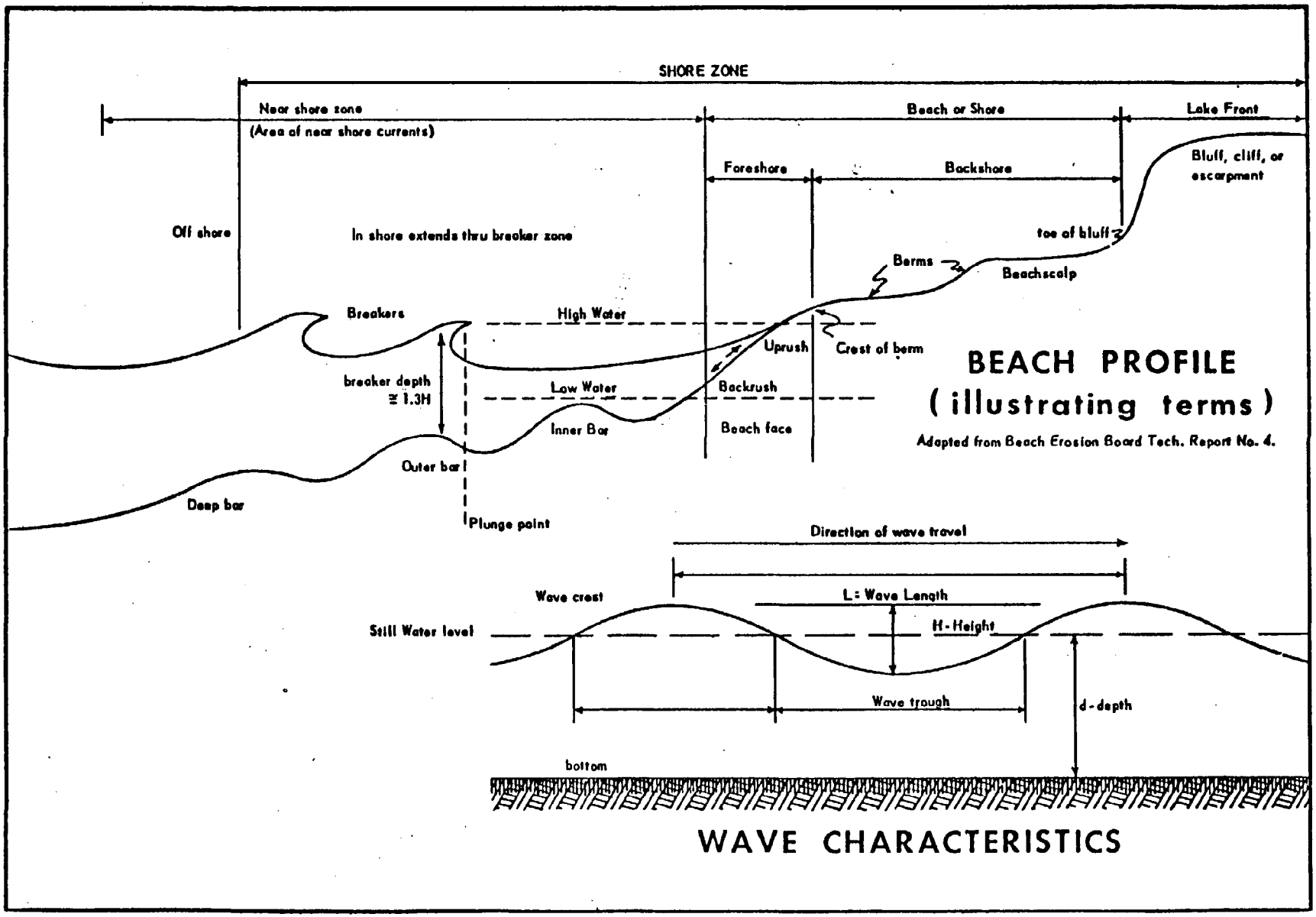
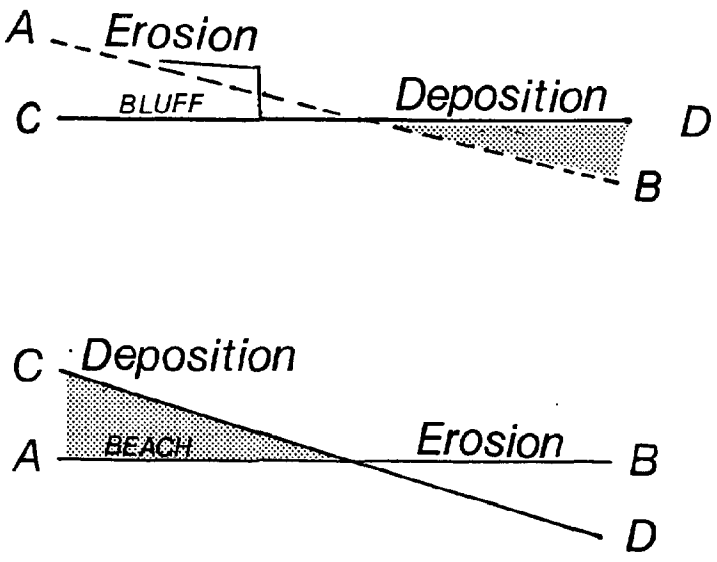

SHORE ZONE
Near shore zone
(Area of near shore currents)
Beach or Shore
Lake Front
Foreshore
Backshore
Bluff, cliff, or escarpment
Off shore
In shore extends thru breaker zone
toe of bluff
Berms
Beachscalp
Breakers
High Water
Uprush
Crest of berm
breaker depth
≅ 1.3H
Low Water
Backrush
Inner Bar
Beach face
Outer bar
Deep bar
Plunge point
BEACH PROFILE
(illustrating terms)
Adapted from Beach Erosion Board Tech. Report No. 4.
Direction of wave travel
Wave crest
L = Wave Length
Still Water level
H - Height
Wave trough
d - depth
bottom
WAVE CHARACTERISTICS

FIGURE 9

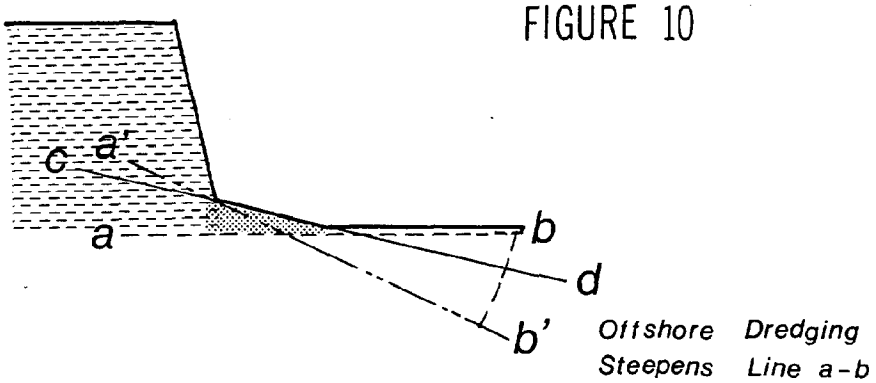


EFFECT OF OFFSHORE DREDGING ON THE PROFILE OF EQUILIBRIUM:

> "Artificial interference with natural profiles by offshore dredging introduces a factor that will have dangerous results if done within the range of profile equilibrium."*

Studies have shown that dredging increases the slope from the shore and, therefore, promotes beach and cliff erosion replacing the material displaced by the dredging activities. Figure 10 illustrates the effect produced when dredging steepens the offshore slope.

FIGURE 10



*Holmes, Principles of Physical Geology, 1965, p. 815.

BLUFF STRUCTURE AND GENERAL GEOLOGIC RELATIONSHIPS:

General Geology

The Coastal Zone of Erie County lies within the glaciated section of the Appalachian Plateau and the Eastern Lake section of the central lowlands. The shore area itself is the remnant of former lake levels of Lake Erie producing lake plains of very low relief. The bluff produced by the present elevation of the lake above sea level is the most outstanding characteristic. A number of streams drain the lake plain producing cuts of various dimensions. These streams drain a relatively small watershed with a north-south drainage divide lying close to the coastal zone.

Bedrock underlies the area and dips generally to the southwest and is exposed on the bluff face, as well as in association with stream cuts and road cuts in the area. The oldest of the bedrock sections is exposed along the bluff zone. The area has seen two glacial advances and retreats with resultant deposition of materials over bedrock. On the lake plain, the glacial tills are covered over by lacustrine deposits.

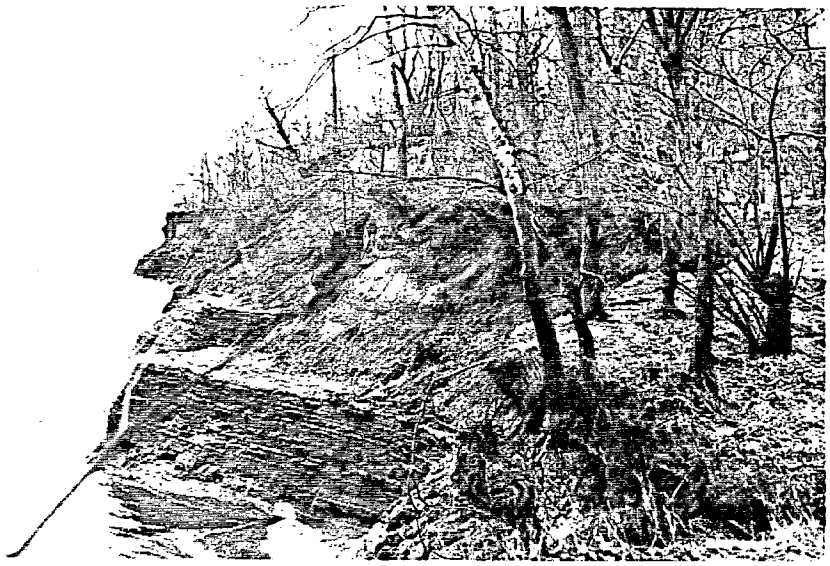
The accompanying diagrams illustrate the character and extent of the general geologic structure of the coastal zone. Fugure 11 illustrates the surficial deposits in Erie County. The deposits at the crest of the bluff have been identified as bedded sands, silt and clay, and sand and gravels. Figure 12 shows the general cross section of the area with thickness and geologic age of materials represented. The Upper Devonian sequence exposed on the bluff face is further refined in Figure 13, showing the interbedding taking place between sandstones and shales. Because of this lithologic change, differential weathering of the bedrock takes place as evidenced by the shelf-like characteristics apparent in rock exposures at the base of the bluff.

Cuspate features are found in the bedrock sections of the East County. While not conclusive, these dramatic features are probably the result of jointing in the bedrock. The energy brought to the exposed rock face by waves results in hydraulic pressure which enlarges the joint to dimensions of over 100 feet. The result is the formation of rectilinear cusps that are rounded by abrasion or corrasion in the shore zone.

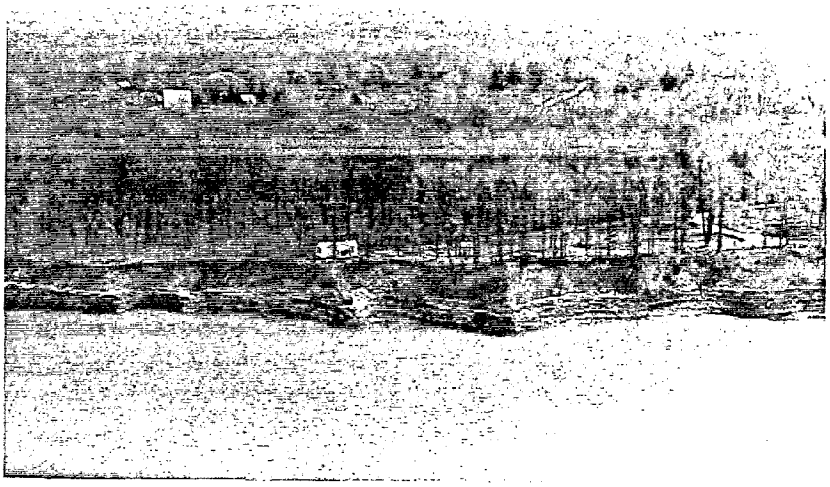
The major geological factor affecting bluff recession on the lakeshore is the difference in bedrock exposure. Generally, in the west county shoreline there is very little bedrock shale exposed above the surface of the lake. Consequently, the bluff toe and bluff face are extremely vulnerable to wave attack. In the east county, there is bedrock exposure in thickness from one to 25 feet. This provides a certain measure of protection to the bluff which is reflected in the generally lower rates of recession in the east county.

BLUFF STRUCTURE:

A typical section of bluff in the west county area would be east of Elk Creek, where the bluffs are approximately 80 feet high. The bluff consists of shale at the water line, with coarse-grained till overlying the shale, and a thick clay sequence, probably lacustrine, overlying that, all covered by sands of lacustrine origin.



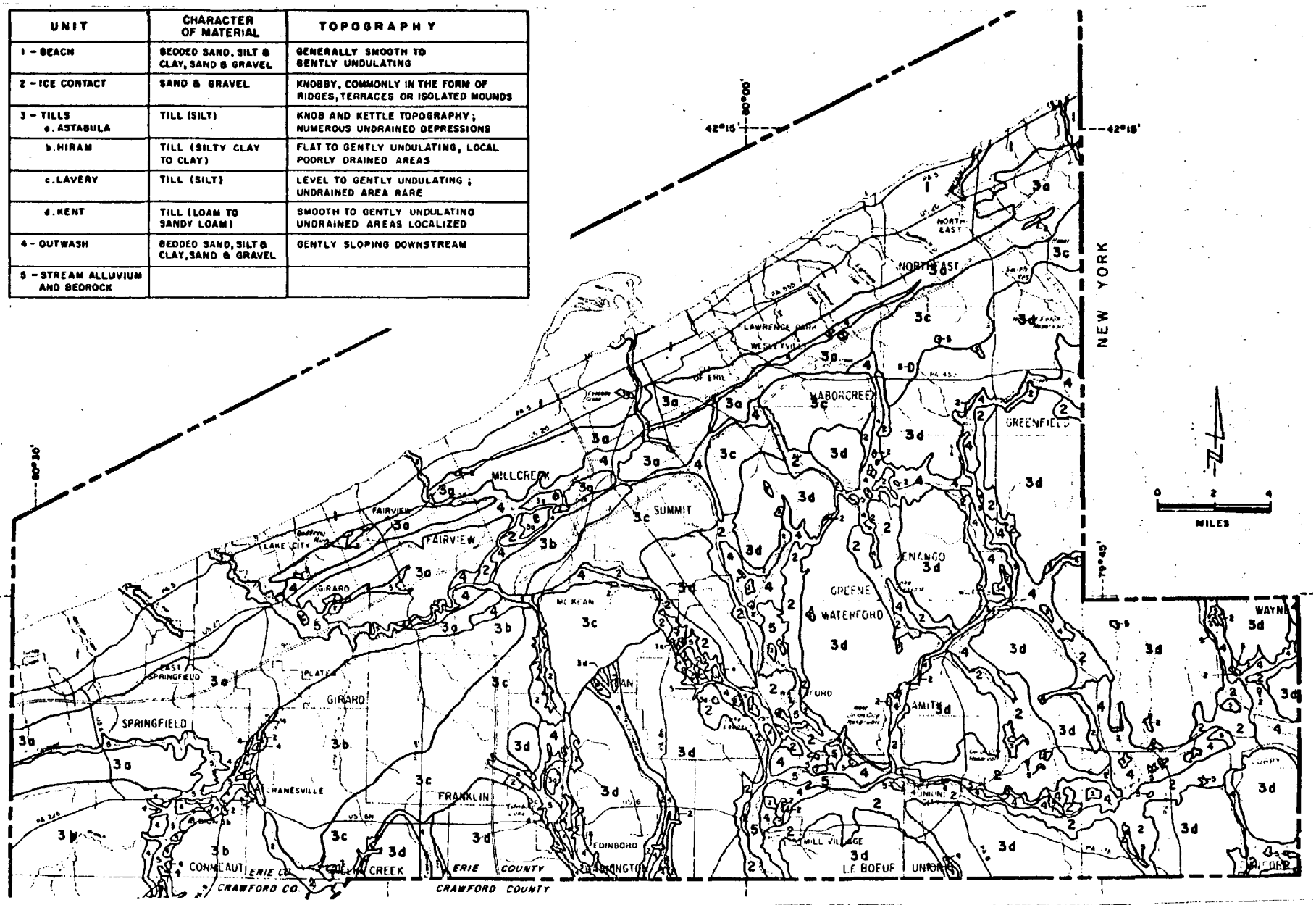
Above: Cuspate features in bedrock, Harborcreek Township



Above: Aerial view of cuspate features, typical of much of the eastern shoreline

FIGURE 11

UNIT	CHARACTER OF MATERIAL	TOPOGRAPHY
1 - BEACH	BEDDED SAND, SILT & CLAY, SAND & GRAVEL	GENERALLY SMOOTH TO GENTLY UNDULATING
2 - ICE CONTACT	SAND & GRAVEL	KNOBBY, COMMONLY IN THE FORM OF RIDGES, TERRACES OR ISOLATED MOUNDS
3 - TILLS a. ASTABULA	TILL (SILT)	KNOB AND KETTLE TOPOGRAPHY; NUMEROUS UNDRAINED DEPRESSIONS
b. HIRAM	TILL (SILTY CLAY TO CLAY)	FLAT TO GENTLY UNDULATING, LOCAL POORLY DRAINED AREAS
c. LAVERY	TILL (SILT)	LEVEL TO GENTLY UNDULATING; UNDRAINED AREA RARE
d. KENT	TILL (LOAM TO SANDY LOAM)	SMOOTH TO GENTLY UNDULATING UNDRAINED AREAS LOCALIZED
4 - OUTWASH	BEDDED SAND, SILT & CLAY, SAND & GRAVEL	GENTLY SLOPING DOWNSTREAM
5 - STREAM ALLUVIUM AND BEDROCK		



GENERALIZED GEOLOGIC MAP, SURFICIAL DEPOSITS

Pennsylvania Geological Survey
SOURCE: Engineering-Science Inc., 1974.

FIGURE 12

GENERALIZED GEOLOGIC CROSSECTION

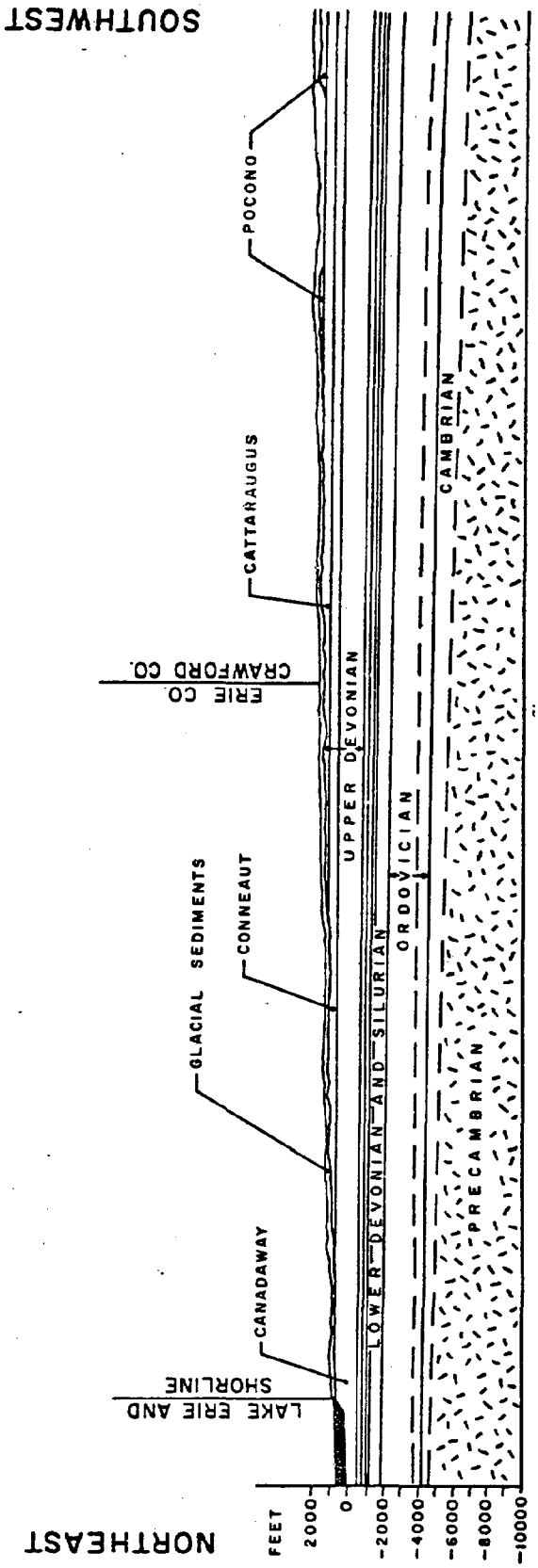
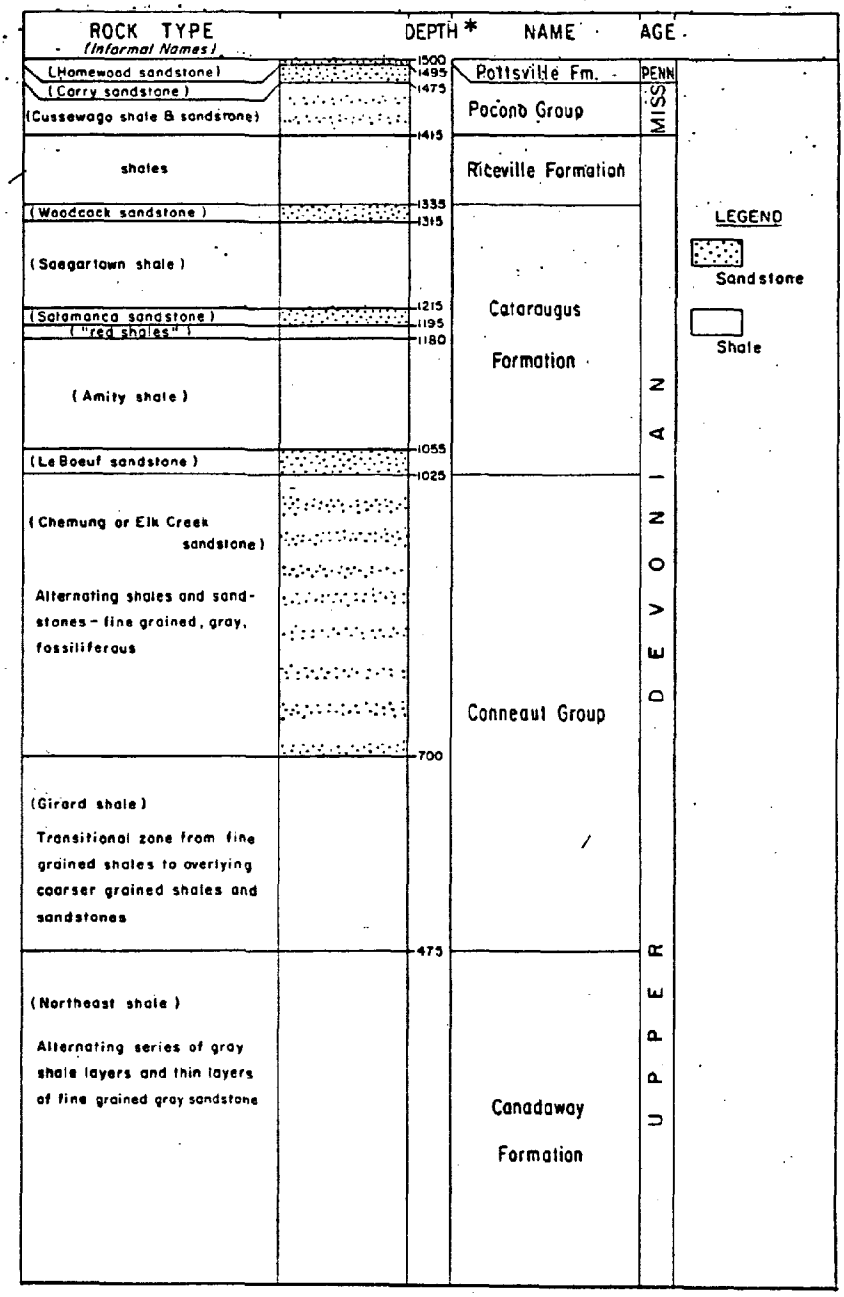


FIGURE 13

BEDROCK COLUMN SHOWING UNITS EXPOSED AT THE SURFACE THROUGHOUT ERIE COUNTY



* Height above Lake Erie level (571 feet above sea level).

SOURCE: Tomikel & Shepps, 1967. p. 28

Above: Glacial tills overlain by clay and sand deposits

Above: Typical section; bedrock at base, coarse grained tills, lacustrine clays and sands

The till is approximately five feet thick in this area. The clay sequence is silty and blue in color. The sands above are generally a characteristic yellow and vary in thickness over the section.

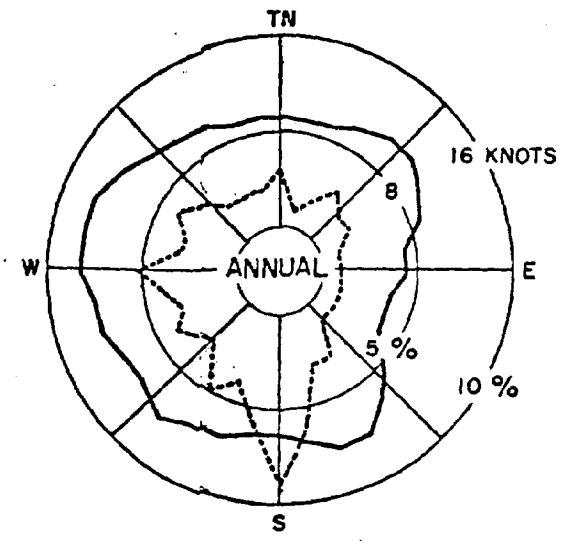
Soil associations in the bluff crest are generally of the Rimer-Wauseon-Berrien association developed in sandy sediments underlain at shallow depths by gray calcareous silt deposits. The somewhat poorly drained River soils make up over two-thirds of the area west of the city of Erie. East of the city, the soils are generally of the Allis-Ellery-Alden association, developed on very thin glacial tills over shale. Slow permeability and high water tables produce high quantities of subsurface runoff existing within the bluff zone producing negative effects on recession due to shear failure.

WIND

Winds provide the energy for current flow and waves, both of which affect the relative stability of the shoreline. A series of wind diagrams for the study area is presented and illustrates the predominant direction of wind, as well as velocity, for each month. The prevailing winds are out of the south, but of extreme importance to the shoreline is the direction from which storms are likely to appear in the critical months of November, before ice can be expected to protect the shore; and March, April and May during seasonal high water and spring storms. The diagrams indicate that, in November, winds tend to be of high velocity essentially from the west to northwest. This direction and velocity has maximum impact on the coastal zone manifested by debilitating storms during this period. If ice cover and ice dunes are not present, the damaging winter winds operate for the entire season. This has been the case for the past two years.

Wind in the spring and early summer tends to be of lower velocity and from the south to southwest quarter. Because of the configuration of the coast with respect to wind direction, only an occasional storm has influence on the production of destructive processes.

FIGURE 14



LEGEND

WIND DIRECTION, PERCENT OF OBSERVATION

WIND VELOCITY, KNOTS

DIRECTION INDICATES ORIGIN OF WINDS

WIND PATTERNS
PORT ERIE AIRPORT
1965 TO 1969

FIGURE 14 (con't)

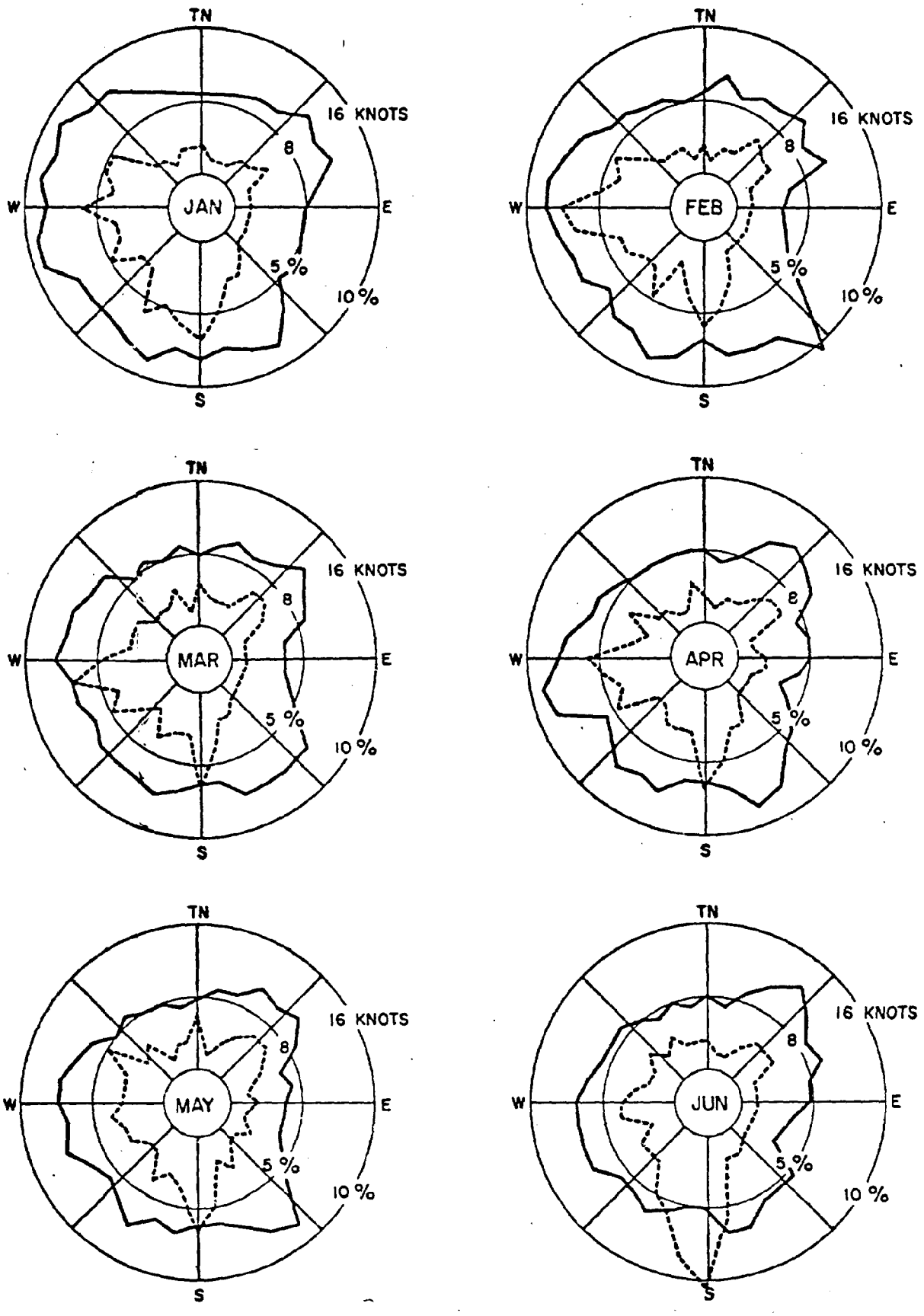
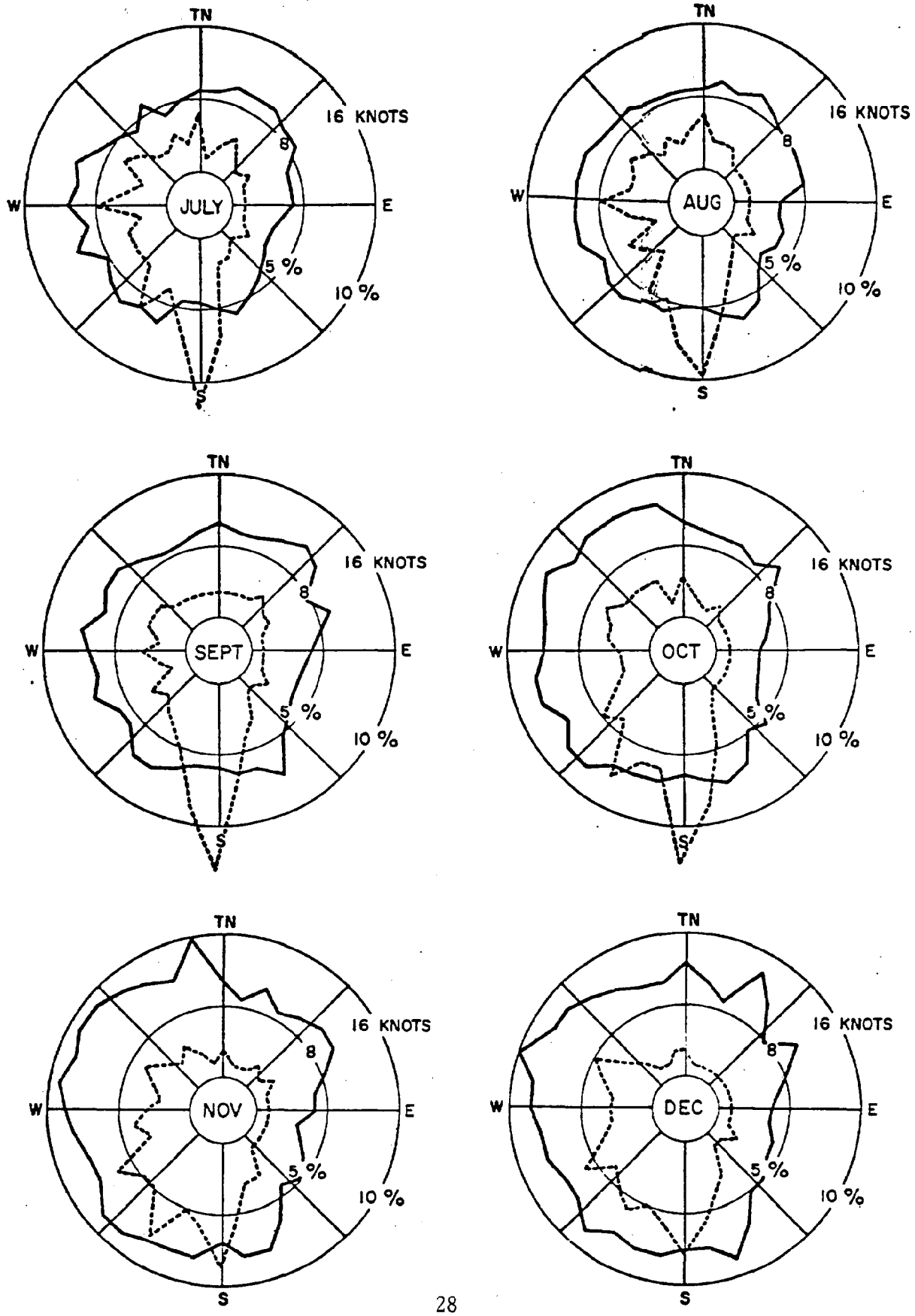


FIGURE 14 (con't)



LONGSHORE TRANSPORT:

As indicated by the summer surface and summer bottom current diagrams (Figures 15 and 16), the longshore drift is from west to east over the entire beach. Any materials introduced into the longshore system by stream deposition are then carried along the shore nourishing the beaches to the east. Conditions on the lake, however, mentioned in the previous section, have caused the offshore movement of these materials. During more normal periods the sediment produced by the streams will deposit along the beach face over much of the reach. The major interruption to the system is Presque Isle which effectively terminates the eastward movement at that point. As a result, even during low lake levels, sand does not begin to accumulate again in significant amount until the area east of Lawrence Park Township.

These sandy beaches are of extreme importance to the protection of the bluffs behind. A good supply of sand at the appropriate time is found to give better coastal protection than groins or seawalls. If the sand is absent, the bluff is open for attack and the result is accelerated bluff recession. There is very good substantiation of this in the recession rate data presented in this report.

GROUNDWATER SEEPAGE, SURFACE RUNOFF, ICE AND PRECIPITATION IMPACT, AND ARTIFICIAL DRAINAGE:

The above elements are factors affecting the face of the bluff and all will be dealt with in this section.

The runoff of surface water as an energy factor contributes to recession and erosion, with respect to the bluff face, in unconsolidated material. Availability of water for this system is indicated in the accompanying NOAA abstract for Erie weather and the Rainfall Intensity Diagram (Figure 18). Sheet runoff from beyond crest as well as down the face itself produces mini-drainage features that, if unchecked by vegetation, can deepen significantly, producing irregularity of form and resultant recession. Efforts to channel this flow by drain pipes exiting at crest of mid-slope compounds the problem since it collects water from a large area and channels it to one location. The result is significant erosion. We observed this phenomena over all sections of the reach and have found it to be a significant factor. In some cases, the property owner has extended the drain pipe down the face of the bluff to the shore zone. It appears that this would be a sound practice.

The flow of subsurface water and/or ground water is a leading contributor to instability on the bluff. The emergence of subsurface water along a spring line in a bluff face is quite common in Erie County, especially in the spring. This presence is a great significance in mass wasting processes producing internal lubrication permitting the downward movement of material by gravity. This effect is magnified by agricultural drainage, especially in the east county. Historically, farmers in the area have buried drainage systems to maximize field potential or to remove subsurface water during the spring. Many of these drainage tiles exit directly on the bluff face with the expected result.

It should also be mentioned that individual property owners have found it convenient to drain effluent fields onto the bluff face to reduce the impact of poor soil conditions on on-lot sewage disposal systems. As in the case of the other drainage diversions mentioned, the effect is to concentrate water in

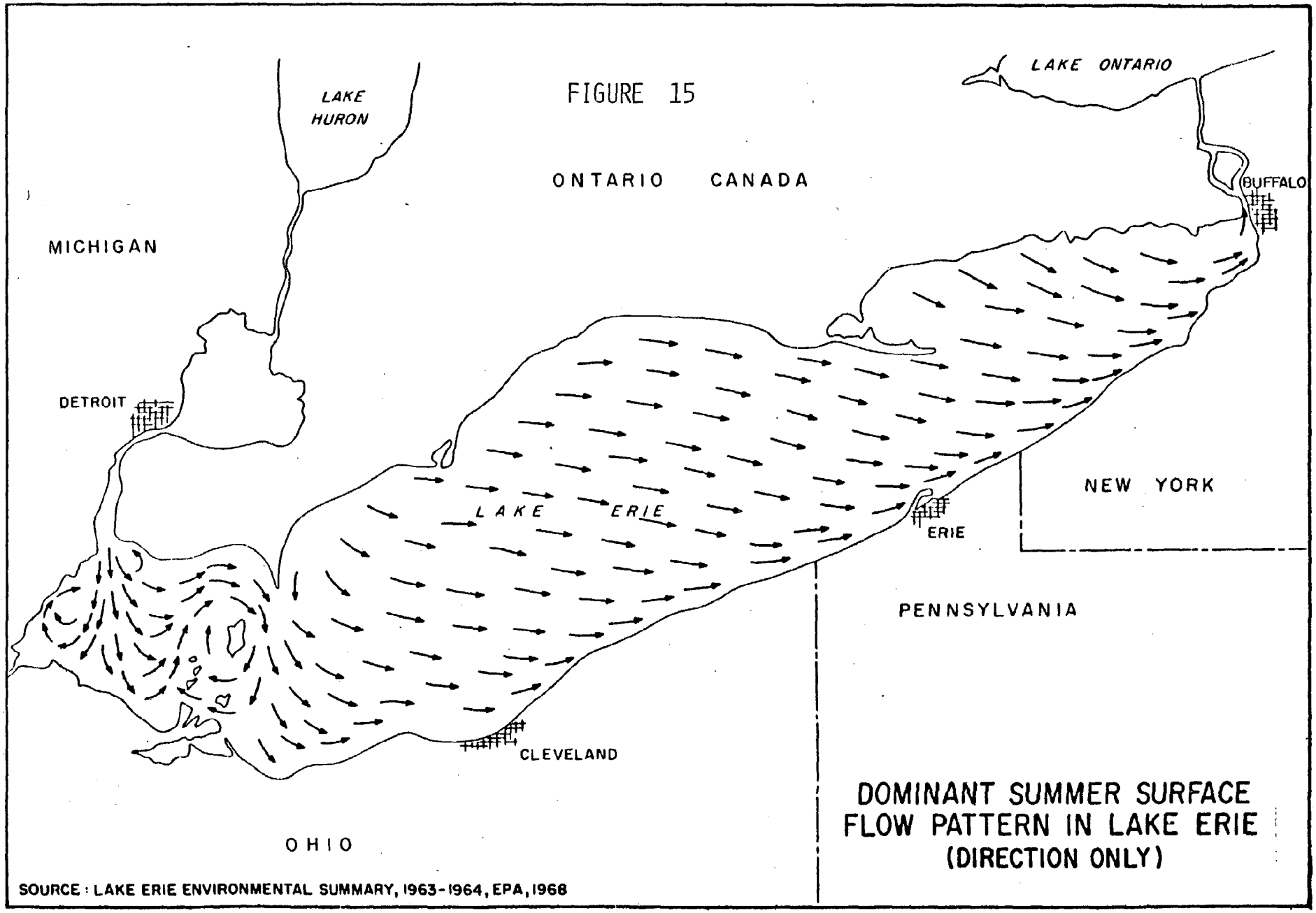


FIGURE 15
LAKE HURON
ONTARIO CANADA
LAKE ONTARIO
BUFFALO
MICHIGAN
DETROIT
LAKE ERIE
NEW YORK
ERIE
PENNSYLVANIA
CLEVELAND
OHIO
DOMINANT SUMMER SURFACE FLOW PATTERN IN LAKE ERIE (DIRECTION ONLY)
SOURCE : LAKE ERIE ENVIRONMENTAL SUMMARY, 1963-1964, EPA, 1968

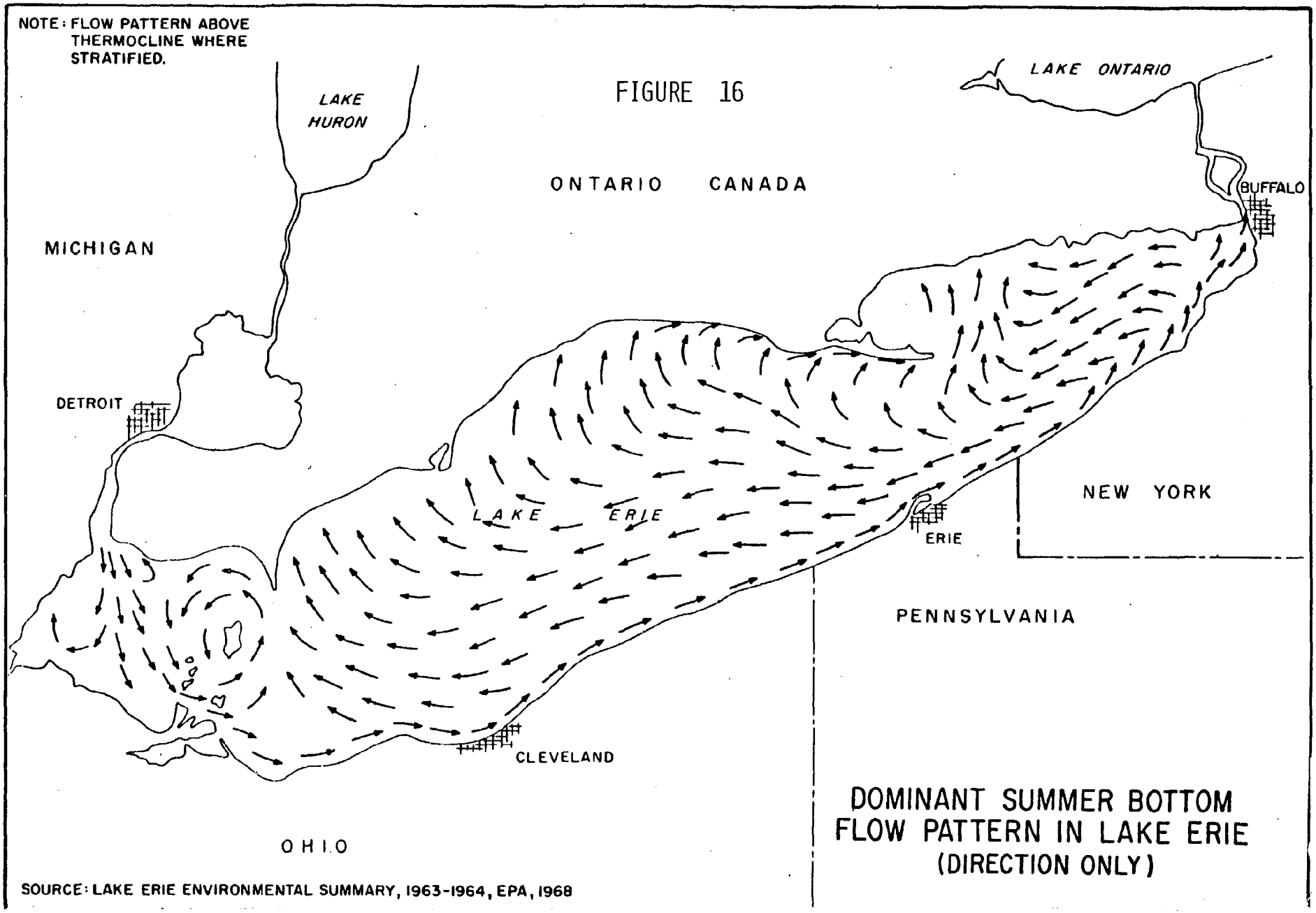


FIGURE 16

DOMINANT SUMMER BOTTOM FLOW PATTERN IN LAKE ERIE (DIRECTION ONLY)

SOURCE: LAKE ERIE ENVIRONMENTAL SUMMARY, 1963-1964, EPA, 1968

one location maximizing the energy available for erosion.

Also, drainage from roads in the area have had some effect. The location of diversionary ditches should be placed so as not to concentrate water in the crest area.

Raindrop impact on the bluff face and the effects of frost action are minor compared to the other processes mentioned, but are a factor. Each of these processes prepared the surface by loosening materials and facilitating their removal by some other agent. The effect is magnified when the slope is devoid of vegetation.

ICE COVER ON LAKE ERIE:

Normally, the shoreline of Erie County is protected by freeze-up of water on the lake (Figure 17). With the lake effectively removed as a force and with ground water and surface water essentially absent, the bluff is offered a period of relative stability. When climatic conditions in variance with the norm occur, however, recession and erosion will continue through the winter months. For the past two years, ice cover on Lake Erie has been sporadic and never continuous. Mild temperatures have produced fewer freezing degree days (Figure 17b) than average so that ground water was active for extended periods of time. As a result, conditions already worsened by high lake levels have reached critical proportions as a result of the loss of protection by ice and freezing. It can probably be stated that this combination has produced accelerated erosion and recession unequalled in recent history for a short period.

SHORE PROTECTION DEVICES:

Shore protection devices come in all shapes and sizes and vary in degree of success. The larger ones, being more costly, are obviously financed through governmental cooperation and usually protect public land. Some of the structures in place on the Erie County shoreline, though private, are quite extensive. Most structures, however, protecting individual properties are relatively small.

The following are types of structures one could expect to find:

Revetments and seawalls
Groins
Breakwaters

The approximate locations of each are described in the section covering bluff physiography and shoreline description. A groin essentially is a structure placed perpendicular to the shore to intercept the sand being carried by the longshore transport system. There is, therefore, an accumulation of sand upstream in the system, while downstream a scalloped appearance is produced by lack of material and an eddy effect as waves round the tip of the groin. This effect will be further explained below. We found groins of various sizes and constructed of materials varying from timbers, cement filled drums, concrete, rocks, precast blocks, and gabions. Most of these were individual efforts having varying degrees of success.

A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

LOCAL CLIMATOLOGICAL DAT

ANNUAL SUMMARY WITH COMPARATIVE DATA

ERIE, PENNSYLVANIA

FIGURE 17

1972

U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRA ENVIRONMENTAL DATA SERVICE

NARRATIVE CLIMATOLOGICAL SUMMARY

Erie is located on the southeast shore of Lake Erie and observations are now made at Erie International Airport, which is 6 miles southwest of the center of the City and about 1 mile from the lake shore. The terrain rises gradually in a series of ridges paralleling the shore line to 500 feet above the lake level 3 to 4 miles inland and to 1,000 feet above the lake about 15 miles inland. This upslope usually increases the amount of snowfall from instability showers from off the lake to the south of the City somewhat higher than the fall along the immediate shoreline.

During the winter months the many cold airmasses advancing southward from Canada are modified considerably by the relatively warm waters of the lake. However, these conditions also produce an excess of cloudiness and frequent snow from November through March.

Spring weather is quite variable in Erie, but generally is cloudy and cool. Nearness to the lake frequently prevents killing frosts that are observed further south. This has led to the establishment of numerous vineyards and fruit orchards in a narrow belt extending along the shore. The last killing frost in the spring curred on May 25, while the average da April 20. In summer heat waves are temp by cooling lake breezes that may extend se miles inland, and days with temperatures a 90° are infrequent. Summer thunderstorms less frequent and usually less destructiv Erie than inland areas due to the stabil effects of Lake Erie and mostly occur frontal passages.

Autumn, with long dry periods and an abund of sunshine, is usually the most pleasant pe of the year in Erie. The growing seasc extended by the influence of the warmer wa of the Lake. The average date of the first ki frost in the fall is November 1, while the ear date is October 7.

Precipitation is well distributed throughou year, although the number of days with mea able amounts varies considerably from a average of about one day in three for the mc of June through September to about one-ha the days for November through January snow flurries and squalls prevail from of lake.

AVERAGE TEMPERATURE FIGURE 17A

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1933	26.8	29.6	38.6	47.4	59.7	71.0	73.6	70.2	67.0	52.5	37.6	31.7	50.9
1934	30.6	14.0	30.8	45.0	60.8	71.8	74.6	68.7	67.6	52.0	46.2	29.8	49.3
1935	27.1	26.0	39.7	43.8	51.9	65.4	75.6	71.8	62.4	53.6	42.6	26.6	48.9
1936	23.6	19.4	37.7	42.4	61.2	67.2	74.0	72.7	66.8	53.6	37.5	35.4	49.3
1937	34.8	30.5	30.4	45.2	58.2	67.2	73.1	74.3	62.7	49.8	40.3	29.1	49.6
#1938	26.8	31.5	40.8	49.0	57.2	68.8	73.6	75.0	61.8	56.0	45.2	32.6	51.4
1939	30.6	30.2	34.4	43.6	59.8	68.8	72.0	72.7	65.8	54.6	40.0	35.3	50.6
1940	19.0	26.9	29.2	41.9	56.0	66.8	72.4	70.8	61.8	51.6	41.4	35.6	47.8
1941	28.4	25.6	28.8	38.5	60.2	68.4	73.6	69.4	67.3	56.6	45.4	37.0	50.9
1942	27.4	23.4	37.4	52.0	60.1	67.8	71.6	70.2	65.0	54.9	42.8	28.4	50.1
1943	25.8	28.4	33.0	40.8	55.6	71.2	72.5	71.4	62.9	51.0	39.8	29.3	48.6
1944	31.3	28.7	32.2	42.6	63.2	69.2	73.2	73.2	65.1	52.8	44.9	28.8	50.4
1945	19.4	28.6	46.8	51.6	52.8	64.8	71.7	71.6	66.6	52.7	44.0	27.6	49.8
1946	30.6	28.5	46.8	46.8	56.1	66.2	72.1	68.0	66.3	59.1	47.6	35.8	52.0
1947	32.7	23.5	31.6	49.2	54.0	68.4	70.4	76.4	66.7	61.5	40.0	32.2	50.0
1948	22.2	28.3	37.1	50.3	54.3	68.6	73.0	71.4	66.4	51.4	48.9	35.2	50.4
1949	35.0	34.7	36.7	45.6	59.5	73.2	75.4	72.6	61.4	59.4	41.5	35.8	52.6
1950	38.1	29.0	31.2	41.5	57.8	67.4	69.5	70.1	63.0	57.5	39.8	28.3	49.4
1951	31.1	30.2	37.6	46.3	58.5	67.1	72.1	69.3	63.6	57.3	37.6	34.0	50.4
#1952	32.1	31.6	35.5	49.3	54.9	70.2	75.5	70.9	65.0	49.6	43.7	35.8	51.3
1953	35.1	34.2	39.0	44.9	58.1	69.3	73.1	72.3	63.1	53.5	44.6	35.2	50.6
1954	26.8	33.6	32.9	49.1	52.8	67.8	68.7	66.6	63.6	54.2	42.0	31.3	49.1
#1955	25.8	28.7	35.4	51.8	58.5	64.6	74.9	73.4	63.5	53.8	39.2	28.3	49.8
1956	25.7	28.9	31.7	43.2	54.1	65.6	68.6	68.9	59.2	55.3	42.3	36.0	48.3
1957	22.9	30.8	38.1	46.1	55.3	67.9	68.8	66.5	61.8	49.7	42.3	35.8	48.8
1958	26.2	21.4	33.4	47.2	54.4	61.2	70.2	67.9	63.0	53.2	43.8	23.2	46.8
1959	23.3	26.3	32.3	47.2	60.1	67.2	71.8	73.5	67.6	53.7	39.9	34.2	50.0
1960	29.8	28.5	24.6	49.9	56.6	66.1	68.4	69.9	66.3	52.1	44.8	25.5	48.6
1961	22.8	29.4	37.4	42.0	53.6	64.7	70.8	70.4	68.5	56.2	43.2	30.9	49.2
1962	23.9	24.5	38.3	46.5	62.6	66.8	69.5	69.0	60.6	54.1	40.4	28.9	48.2
1963	19.8	18.2	37.7	46.8	53.9	68.5	70.8	66.7	59.6	58.7	45.0	25.3	47.5
1964	30.0	24.8	36.6	47.2	60.1	68.6	72.5	66.6	62.7	50.0	45.0	33.2	49.6
#1965	25.8	26.6	29.5	41.6	61.0	64.5	67.5	68.2	66.3	50.5	42.4	36.0	48.4
1966	22.8	26.6	37.0	44.5	51.6	67.5	71.8	69.3	61.1	51.3	43.3	32.3	48.3
1967	32.8	24.2	34.6	47.6	49.6	71.1	68.8	66.6	60.0	53.1	36.9	34.0	48.3
1968	23.5	20.7	36.4	48.3	52.6	65.0	70.1	70.6	68.9	58.1	42.4	30.5	48.4
1969	27.0	25.7	31.8	47.2	54.7	62.6	69.0	69.6	61.7	50.0	38.3	25.8	47.0
1970	16.8	23.1	28.4	45.1	58.2	63.9	68.9	68.0	62.8	53.0	40.4	30.8	46.6
1971	22.0	27.3	30.0	40.6	51.9	66.0	66.9	64.7	64.1	57.0	39.3	35.9	47.2
1972	26.9	22.9	29.8	40.0	55.6	59.8	68.4	66.1	61.1	47.2	37.3	33.3	45.7
RECORD MEAN	27.4	26.7	34.3	45.4	56.6	66.6	71.4	69.9	64.1	53.4	41.8	31.7	49.1
MAX	34.0	33.8	41.7	53.3	64.8	74.5	78.9	77.4	71.7	60.7	47.9	37.5	56.4
MIN	20.8	19.5	26.9	37.4	48.3	58.6	63.8	62.3	56.5	46.0	35.7	25.9	41.8

TOTAL DEGREE DAYS FIGURE 17B

ERIE, PENNSYLVANIA

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1933-34	0	1	53	388	826	1032	1065	1428	1062	600	178	12	6645
1934-35	0	39	52	402	562	1089	1176	1090	784	642	415	66	6317
1935-36	0	25	120	354	672	1190	1282	1321	846	680	206	44	6740
1936-37	2	6	86	365	825	916	938	966	1072	592	234	24	6026
#1937-38	7	0	152	478	742	1112	1184	938	756	494	263	34	6160
1938-39	0	0	122	296	597	1002	1068	972	981	647	207	24	5886
1939-40	6	0	81	347	748	920	1426	1104	1108	692	294	58	6784
1940-41	22	41	124	422	706	912	1134	1104	1122	448	210	54	6299
1941-42	3	16	59	297	587	896	1168	1161	854	407	215	39	5702
1942-43	6	14	120	315	665	1138	1217	1028	931	735	303	42	6514
1943-44	4	9	137	432	757	1106	1044	1051	1018	671	136	37	6402
1944-45	0	9	90	390	603	1124	1413	1020	574	419	399	129	6170
1945-46	5	6	83	381	630	1162	1066	1021	566	549	288	98	5855
1946-47	0	22	73	211	524	906	1000	1162	1035	593	343	73	5949
1947-48	13	3	118	154	748	1018	1324	1064	863	444	333	54	6138
1948-49	3	5	67	423	487	925	929	866	878	583	217	30	5393
1949-50	0	5	147	219	705	900	830	1003	1041	700	234	44	5828
1950-51	10	8	101	244	759	1131	1046	966	843	558	224	36	5926
1951-52	1	17	102	272	817	955	1013	961	907	465	308	31	5849
#1952-53	0	9	85	478	571	896	982	857	799	593	232	32	5534
1953-54	2	0	136	360	602	916	1178	872	990	472	393	54	5975
1954-55	17	37	110	363	685	1036	1209	1009	912	392	247	82	6099
#1955-56	0	7	112	347	765	1132	1213	1039	1027	647	365	96	6750
1956-57	12	19	202	298	675	891	1298	951	920	526	314	51	6157
1957-58	21	38	155	467	675	898	1196	1215	973	529	330	140	6637
1958-59	3	34	112	365	629	1287	1286	1077	1002	530	222	69	6616
1959-60	1	0	91	361	748	947	1086	1050	1245	464	277	52	6322
1960-61	25	6	49	397	597	1221	1302	989	848	681	370	96	6581
1961-62	23	10	66	276	648	1051	1266	1125	977	578	168	59	6247
1962-63	7	27	173	338	731	1174	1394	1306	839	543	350	64	6946
1963-64	20	28	173	221	594	1222	1077	1158	874	530	195	91	6183
1964-65	3	53	140	461	596	978	1209	1072	1093	696	174	105	6580
#1965-66	28	44	76	441	673	892	1302	1068	842	609	417	64	6456
1966-67	5	10	151	420	644	1006	993	1137	941	518	471	18	6314
1967-68	25	32	164	374	835	953	1280	1277	881	494	377	81	6775
1968-69	20	26	55	333	671	1063	1169	1093	1020	528	324	145	6447
1969-70	20	20	169	462	796	1211	1488	1169	1129	605	235	103	7407
1970-71	18	18	125	366	731	1056	1324	1048	1078	723	404	68	6959
1971-72	32	55	97	242	763	895	1172	1217	1082	742	287	184	6768
1972-73	55	47	144	546	820	976							

TOTAL PRECIPITATION FIGURE 17C

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1933	1.13	1.31	2.74	2.80	2.35	1.75	1.12	2.45	3.82	2.31	2.55	2.67	27.00
1934	2.04	1.01	2.36	2.10	0.55	1.45	1.90	3.15	2.93	1.89	2.96	1.50	23.84
1935	2.02	2.60	2.21	1.17	2.20	2.68	7.34	2.02	3.14	1.75	1.57	2.62	31.32
1936	1.58	2.37	3.80	2.97	1.27	1.75	0.91	1.28	1.52	2.86	4.11	1.19	25.81
1937	6.05	2.15	1.23	7.03	2.10	6.64	1.60	4.45	2.56	3.75	1.89	3.55	43.00
#1938	1.46	4.12	2.96	3.61	3.10	3.38	2.21	3.68	7.42	1.72	3.89	1.93	39.48
1939	2.71	4.13	3.75	3.22	2.72	1.73	4.57	2.10	4.84	4.56	2.16	2.96	39.45
1940	2.15	3.12	2.28	3.12	4.72	2.73	0.95	3.16	3.14	2.12	2.81	3.50	33.80
1941	2.40	1.28	1.16	1.58	2.04	2.58	2.77	3.31	1.52	3.20	2.10	1.56	25.50
1942	1.84	2.14	3.22	2.79	6.47	1.53	4.12	2.87	6.42	4.36	3.67	2.08	41.31
1943	0.93	1.25	2.51	4.02	6.41	1.65	6.27	1.49	3.38	6.40	2.09	1.13	37.53
1944	0.85	2.22	3.23	5.04	4.32	3.91	2.56	3.35	4.51	3.95	2.09	4.69	40.72
1945	3.01	2.47	4.52	3.62	2.88	4.85	2.69	2.26	7.62	6.11	2.97	1.97	44.97
1946	1.11	2.66	2.93	1.31	7.68	5.84	4.47	2.25	1.82	4.37	3.48	3.18	40.88
1947	4.40	2.77	1.87	8.88	5.98	2.78	13.27	2.06	3.65	0.54	3.22	2.30	54.72
1948	2.07	2.67	4.71	5.19	3.79	6.12	4.22	1.71	1.01	5.01	3.99	2.13	42.62
1949	3.55	2.05	3.28	2.67	3.70	1.21	5.04	7.54	4.24	1.31	3.34	2.94	40.87
1950	6.25	4.97	4.41	4.12	2.64	2.19	6.12	3.98	4.48	3.71	8.93	3.03	54.83
1951	3.59	3.09	4.10	4.28	2.78	4.17	2.13	1.26	2.95	2.25	4.34	3.99	38.93
#1952	3.79	2.80	2.02	2.12	4.82	2.70	1.63	5.31	3.51	0.94	2.78	2.46	35.08
1953	3.36	1.29	4.15	2.16	6.90	1.25	3.18	1.04	3.34	0.40	2.79	3.14	33.00
1954	1.75	2.03	4.32	0.28	2.04	4.41	1.51	2.49	2.47	9.87	1.95	2.94	42.06
#1955	1.43	1.88	3.06	2.63	1.81	1.03	2.60	5.71	2.28	5.53	2.83	1.98	32.77
1956	1.31	2.45	3.74	3.65	5.59	1.58	7.11	6.61	1.79	1.19	5.60	2.81	43.43
1957	2.93	1.73	1.97	0.33	3.29	7.74	1.75	1.43	4.03	1.98	2.26	2.20	38.24
1958	2.86	1.52	0.68	3.03	1.60	4.84	4.65	5.64	6.01	2.21	4.03	2.73	39.80
1959	4.59	3.08	3.14	3.38	2.95	3.40	2.31	0.58	5.85	6.29	4.76	3.58	43.51
1960	3.09	2.55	0.63	2.18	3.66	2.60	2.95	2.03	1.45	2.21	2.68	1.38	27.41
1961	1.13	4.03	2.13	7.11	2.05	3.90	3.25	3.12	2.16	2.56	2.22	2.84	36.50
1962	3.30	1.84	1.17	1.84	1.45	4.98	2.39	4.56	4.94	4.02	2.13	4.28	36.90
1963	1.51	0.95	2.84	2.94	2.02	0.85	2.71	2.62	1.46	1.13	5.91	3.17	28.11
1964	2.35	1.39	3.81	3.67	3.75	2.26	3.42	4.60	1.97	2.96	3.08	3.21	36.47
1965	3.86	3.00	3.55	1.66	3.40	3.75	3.48	2.68	2.24	3.84	4.27	2.68	38.41
1966	2.01	1.92	3.47	4.26	2.03	3.82	2.08	3.52	3.24	1.73	5.34	4.32	37.74
1967	0.90	1.67	1.67	4.21	3.15	2.49	4.79	4.48	4.23	2.77	5.19	2.21	37.78
1968	2.98	1.13	1.69	2.64	3.06	2.63	2.34	2.76	2.93	3.40	4.71	4.06	34.33
1969	2.95	0.73	1.43	5.27	5.49	4.88	3.65	1.75	1.99	3.02	2.99	2.43	36.58
1970	1.44	2.09	1.61	2.48	3.23	2.65	7.70	2.03	7.08	3.52	4.87	2.80	41.50
1971	1.63	2.05	1.85	1.81	2.20	2.83	2.67	3.46	3.51	3.48	4.51	4.06	34.06
1972	1.94	2.77	3.95	2.64	4.69	7.50	2.91	3.01	5.37	1.72	3.36	3.69	43.55
RECORD MEAN	2.71	2.40	2.70	3.07	3.35	3.34	3.26	3.11	3.49	3.46	3.44	2.78	37.11

TOTAL SNOWFALL FIGURE 17D

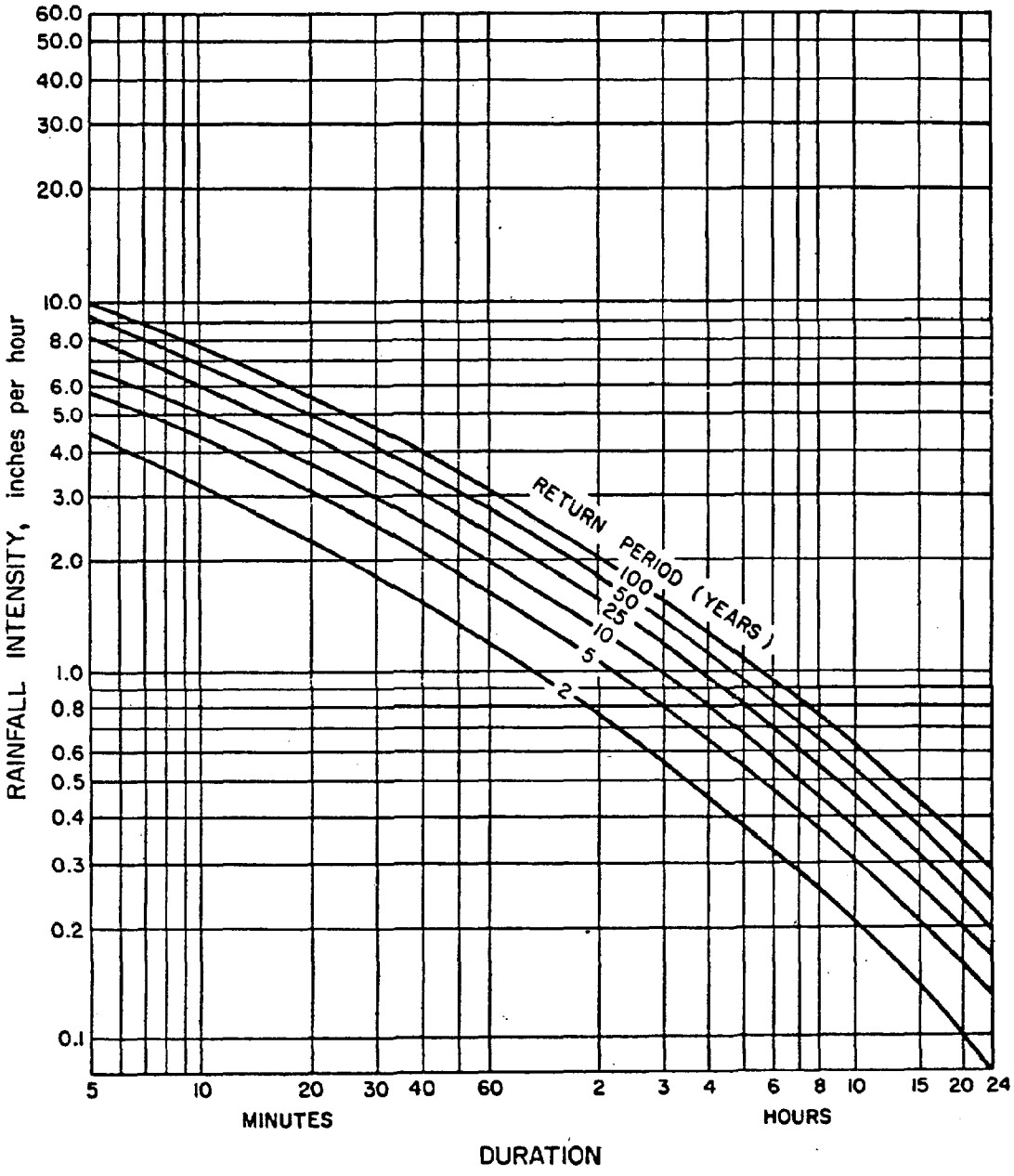
Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1933-34	0.0	0.0	0.0	1.2	11.2	8.1	4.0	10.4	5.5	3.0	0.0	0.0	43.4
1934-35	0.0	0.0	0.0	3.7	2.6	8.2	4.5	15.6	5.5	1.1	0.0	0.0	41.2
1935-36	0.0	0.0	0.0	0.5	0.4	22.7	11.7	11.3	20.4	9.0	0.0	0.0	76.2
1936-37	0.0	0.0	0.0	T	13.4	3.2	7.1	6.5	5.4	T	0.0	0.0	35.6
#1937-38	0.0	0.0	0.0	2.8	7.8	11.6	10.2	2.0	1.1	5.9	0.0	0.0	41.4
1938-39	0.0	0.0	0.0	0.0	8.7	10.2	11.7	12.2	2.9	3.3	0.0	0.0	49.0
1939-40	0.0	0.0	0.0	0.1	T	7.6	18.9	16.3	10.2	5.5	T	0.0	58.6
1940-41	0.0	0.0	0.0	0.3	7.7	10.3	14.9	12.1	5.4	0.0	0.0	0.0	50.7
1941-42	0.0	0.0	0.0	0.0	2.3	3.6	8.5	11.4	11.6	0.7	0.0	0.0	38.1
1942-43	0.0	0.0	T	1.0	2.3	14.5	7.5	7.1	10.6	3.8	0.0	0.0	47.0
1943-44	0.0	0.0	0.0	8.2	6.4	7.8	1.0	12.5	10.7	1.9	0.0	0.0	48.5
1944-45	0.0	0.0	0.0	0.0	1.7	53.6	38.3	14.0	4.1	0.7	0.0	0.0	112.4
1945-46	0.0	0.0	0.0	T	4.1	21.8	7.8	8.5	0.3	T	0.0	0.0	42.5
1946-47	0.0	0.0	0.0	0.0	0.7	14.3	13.4	36.9	20.0	T	T	0.0	85.3
1947-48	0.0	0.0	0.0	0.0	35.1	6.8	19.6	7.7	10.6	T	T	0.0	79.8
1948-49	0.0	0.0	0.0	T	T	7.8	6.4	5.0	12.4	0.7	0.0	0.0	32.3
1949-50	0.0	0.0	T	0.0	7.4	10.6	8.1	12.3	15.8	0.2	0.0	0.0	54.4
1950-51	0.0	0.0	0.0	0.0	46.9	24.0	18.2	12.1	9.8	0.4	0.0	0.0	111.4
1951-52	0.0	0.0	0.0	0.0	11.2	23.0	13.2	15.3	6.8	T	0.0	0.0	69.5
#1952-53	0.0	0.0	0.0	T	5.0	9.7	9.8	10.7	5.5	0.9	0.0	0.0	41.6
1953-54	0.0	0.0	0.0	0.0	6.9	16.6		8.0	14.1	T	T	0.0	
1954-55	0.0	0.0	0.0	4.0	2.0	11.6	10.2	11.0	10.3	T	0.0	0.0	49.1
#1955-56	0.0	0.0	0.0	T	6.4	18.6	11.5	4.5	17.8	4.0	T	0.0	62.8
1956-57	0.0	0.0	0.0	0.0	34.8	10.2	25.6	6.7	13.5	17.2	T	0.0	108.0
1957-58	0.0	0.0	0.0	1.2	7.9	4.7	28.9	12.7	6.6	2.4	0.0	0.0	64.4
1958-59	0.0	0.0	0.0	0.0	15.7	45.0	24.7	7.6	15.5	T	T	0.0	108.5
1959-60	0.0	0.0	0.0	0.0	16.0	12.8	7.3	22.6	11.3	2.6	T	0.0	72.6
1960-61	0.0	0.0	0.0	T	5.3	17.4	23.7	13.6	0.7	8.9	T	0.0	69.6
1961-62	0.0	0.0	0.0	T	0.8	11.9	9.5	14.4	4.5	1.4	0.0	0.0	42.5
1962-63	0.0	0.0	0.0	3.0	0.3	30.5	18.7	12.3	10.9	0.1	0.1	0.0	75.9
1963-64	0.0	0.0	0.0	0.0	6.5	56.0	25.8	19.7	7.4	0.5	0.0	0.0	115.9
1964-65	0.0	0.0	0.0	T	19.9	13.5	16.8	13.7	26.8	2.2	0.0	0.0	92.9
1965-66	0.0	0.0	0.0	T	18.4	5.3	29.9	8.7	17.7	4.8	T	0.0	84.8
1966-67	0.0	0.0	0.0	0.0	7.2	31.4	6.0	13.5	8.8	1.7	T	0.0	68.6
1967-68	0.0	0.0	0.0	T	36.3	13.3	24.2	24.6	9.1	0.4	0.0	0.0	107.9
1968-69	0.0	0.0	0.0	T	9.8	18.8	26.1	13.6	9.4	2.0	0.0	0.0	79.7
1969-70	0.0	0.0	0.0	1.2	11.4	21.9	19.7	21.9	8.9	0.9	0.0	0.0	85.6
1970-71	0.0	0.0	0.0	T	18.0	23.6	26.8	21.4	26.8	2.8	0.0	0.0	120.0
1971-72	0.0	0.0	0.0	T	14.6	9.3	27.3	32.1	7.9	1.1	0.0	0.0	92.3
1972-73	0.0	0.0	0.0	0.6	6.8	18.5							

Record mean values above (not adjusted for instrument location changes listed in the Station Location table) are means for the period beginning in 1847.

# Indicates a break in the data sequence during the year, or season, due to a station move or relocation of instruments. See Station Location table. Data are from City Office locations through August 1953.

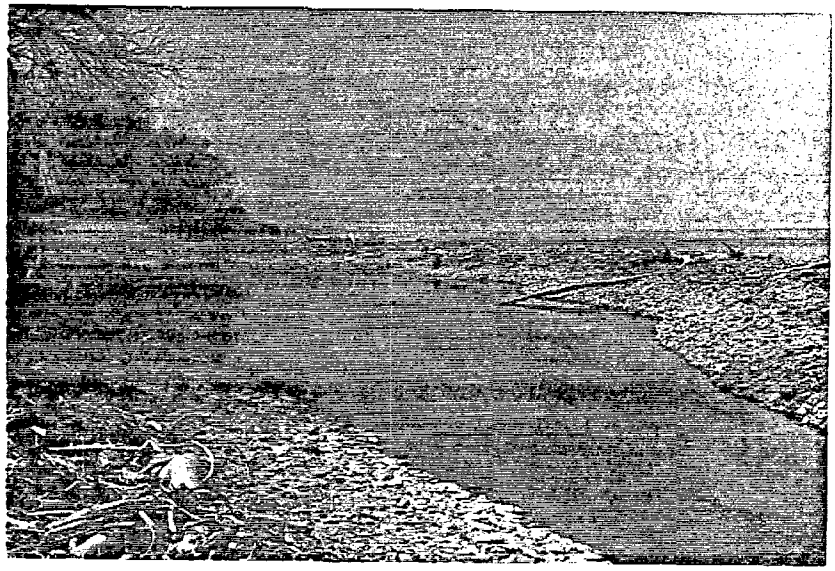
FIGURE 18

RAINFALL-INTENSITY-DURATION-FREQUENCY CURVES ERIE, PENNSYLVANIA 1903-1908, 1910-1922, 1924-1951

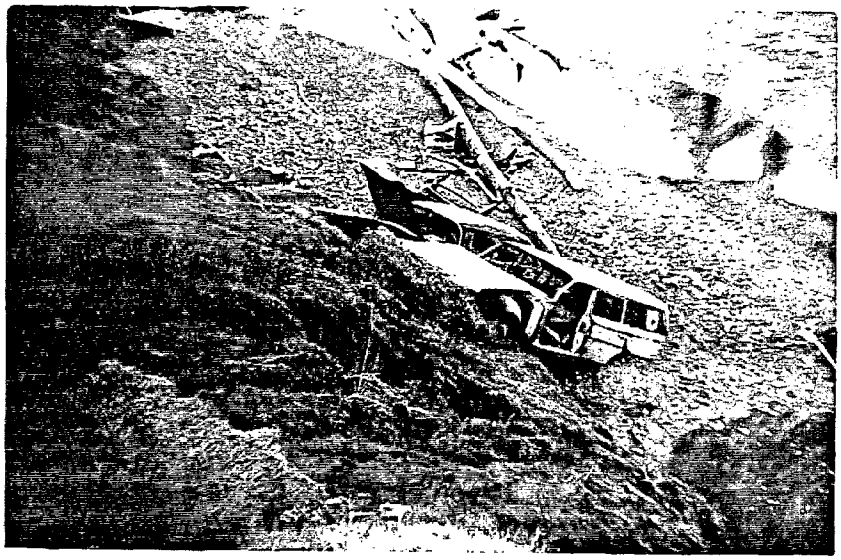


SOURCE: NATIONAL WEATHER SERVICE TECHNICAL REPORT NO. 25

Above: Seawall constructed of rock-filled fence netting

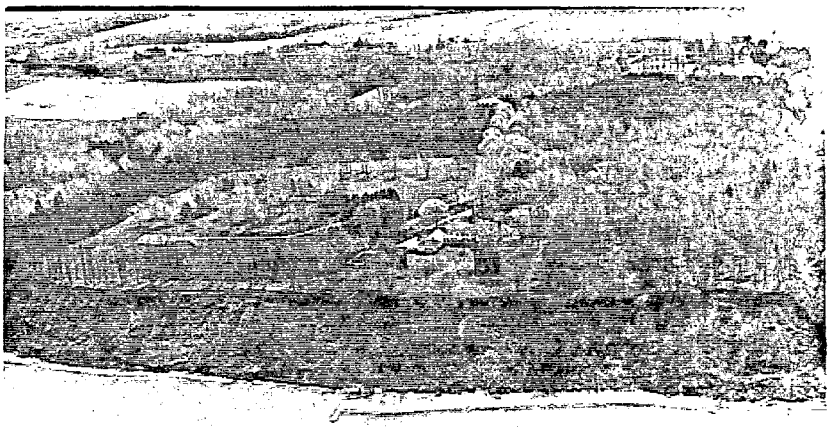


Above: Baymouth bar sheltering small harbor behind

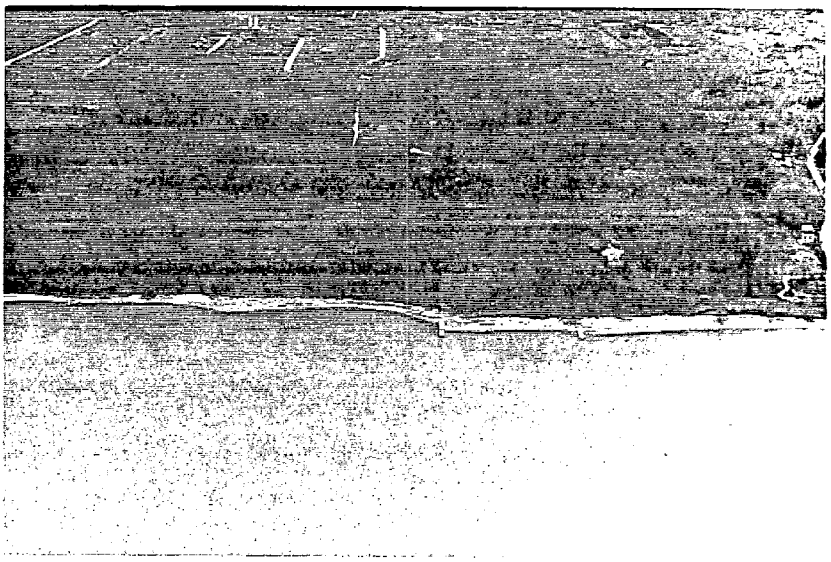


Above: Junked cars at base of bluff, Elk Creek; an attempt to retard slope failure

Above: Steel pipes, 8 feet long, 5 feet in diameter and filled with concrete, offer some protection to this cottage association, East County



Above: Cause and effect: groin construction in center has restricted sand accumulation to the left (East) producing accelerated erosion



Above: Typical groin placement for beach nourishment. Despite high water, sand accumulation is significant.

Seawalls, too, were of varying types of material and usually placed by individuals for the protection of their property or structure. Breakwaters are virtually absent because of the high cost of placement. The Army Corps of Engineers has proposed the construction of breakwaters off Presque Isle to protect the beach nourishment program established many years ago.

It must be noted here that groins can be a mixed blessing as a shoreline protection device. Groins interfere with the replenishment of beaches farther down the coast by robbing them of their former sources of supply. Drifting of materials then does not stop along the starved sections until they finally disappear. The coast behind them, which they had been protecting from erosion, is exposed to increasing attack by the waves. In many areas, we found erosion to accelerate greatly downshore in the transport system after the placement of groins. This "end of groin field phenomena" is readily apparent on Presque Isle and at other Erie County locations and has caused massive reshaping to take place imperiling roads and structures. During high water levels, when sand accumulation is spotty at best, it is quite important that the placement of future groins take into consideration the owner downstream in the longshore transport system. While an individual may successfully defend himself by investing in such a structure, he may maximize the erosion of his neighbor's property.

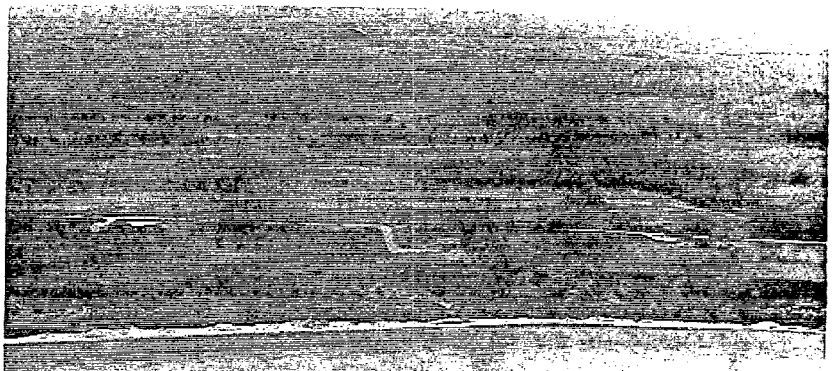
Since the purpose of the groin is to store up sand and it has already been mentioned that sand is the most protective device in preventing erosion of the bluff, it can be expected that, where groin fields are in place, recent recession at these points has been somewhat minimized. In at least one section, however, other processes of recession were extremely active in reducing the bluff despite the fact that the toe was relatively secure from attack.

LAND COVER AND LAND USE:

A cause and effect association related to land cover and land use is apparent in the coastal zone. First, vegetation will offer a measure of protection to the bluff face, decreasing the effects of sheet runoff, frost action, and raindrop impact. Vegetation in the crest zone will protect the lip by root structure, preventing decay. Second, vegetation on the slope or crest is a measure of relative stability. When conditions are stable, vegetation will take root. If conditions produce rapid activity (undercutting, slumping), the vegetation is not capable of withstanding the pressures involved and is removed by slides or toppling. One of the most outstanding features of the bluff face observed during the course of study is the presence of trees being moved about in the littoral, the debris accumulations at the base of the bluff, and the degree of disruption on the face itself. Therefore, vegetation can be seen as an indicator of relevant stability as well as a source of protection against minor attack.

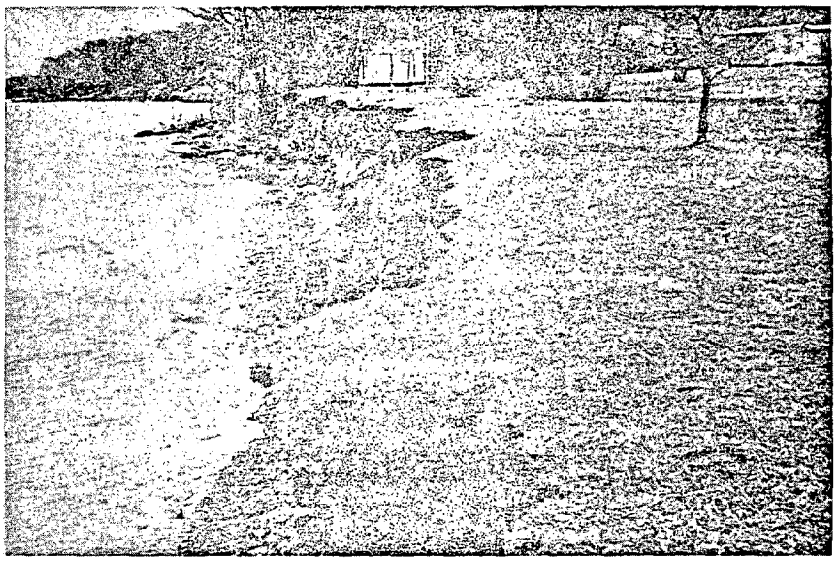
Land use on top of the bluff has a direct effect on the face of the bluff, as already indicated in the discussion on drainage disruption. Property owners on the bluff are tempted to remove much of the standing trees to open a vista on the lake. Generally grasses are maintained to the very edge of the bluff. There is a direct correlation between this change in land cover and the rate of bluff recession at that point. The effect needs more study to determine cause and effect, but generally the absence of dense vegetation allows a greater

Above: Vegetation as an indication of movement - slump block in center with trees upright



Above: Area of rapid recession: land cover beyond bluff is a contributory cause of recession

Above and below: Vegetative disruption on bluff as indication of slope activity



Above: Rapid recent recession evident in bluff unprotected at base and devoid of significant land cover

Below: Truncated hill, rapid recent recession in clay bluffs

amount of surface and subsurface runoff to reach the bluff face. Also, the root structure of a large tree will offer greater protection than a sod layer, which is easily undercut and lost.

SECTION 4
DESCRIPTION AND RESULTS OF FIELD RECONNAISSANCE

DESCRIPTION OF FIELD RECONNAISSANCE:

The coastal Zone of Erie County presents some unique problems for field reconnaissance:

1. The Coastal Zone is a relatively narrow area with vertical differentiation as well as areal extent.

2. The bluff, both in physical character and cultural orientation, is difficult to perceive from any single vantage point.

3. Access to the bluff is generally limited by private use as well as distance from public roads in some cases.

4. Beach areas are non-continuous, limiting observation from this vantage point.

Therefore, to gain a complete, and accurate, insight into the parameters involved, a number of techniques were utilized.

1. On site visitation: The Coastal Zone, as mentioned previously, is accessed by a number of public roads. In many cases, access is direct by roads immediately adjacent to, or servicing, a coastal land use function. Indirect access is also possible by a short walk, usually through private property, to gain access to the bluff zone.

   To gain first hand information, the staff undertook as complete a foot reconnaissance of the entire coastal fringe as access permitted. Field notes, chain measurement, and supportive photography (both black and white prints and color slides) were methods used. As a result, we were able to investigate critical areas closely to establish the nature and extent of problems in each location as well as physical features and land-based causative factors for recession and erosion. Where access permitted, a foot study was made of beach conditions at the toe of the bluff to establish geologic character and use patterns in this zone and to record potential environmental hazards.

   In most cases, where major streams enter the lake, access has been facilitated through establishment of roadways along the stream to the shoreline. Such access has, of course, allowed for development of stream mouths in most cases. Major cottage developments and fishing access areas were examined thoroughly, due to easy access to them.

2. Offshore reconnaissance: Since access to the bluff crest was limited in some cases, and access to the shore area reduced by high bluff conditions, the need for offshore reconnaissance was apparent. The entire Erie County coastline was observed and photographed utilizing small craft with the potential of running close in for observation purposes. From this vantage point, bluff characteristics and use were completely open to view. Active mass wasting on the bluff, invisible from above, could be observed in close proximity, as well as contributing factors of erosion and recession, namely drainage outfalls, groundwater seepage, undercutting of toe, and human activity.

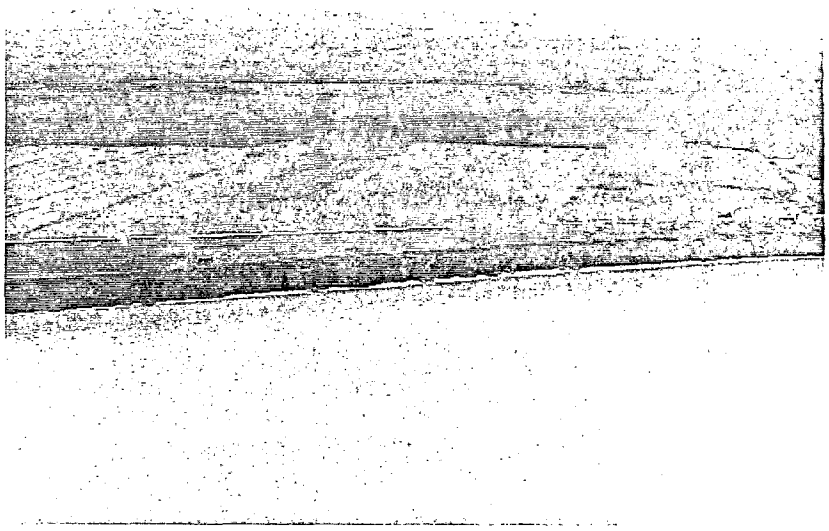
3. Aerial reconnaissance: To establish the character of the coastal zone in its entirety, small aircraft were used for low level reconnaissance. The coast was flown several times from various altitudes to establish a photographic record of the zone from an elevated platform. The record consists of black and white photographs as well as color slides, invaluable for purposes of analysis of current activity and as an excellent base for future study.

   To assist in analyzing and assessing critical areas, a 16mm black and white film was made providing continuous coverage of the coastal zone. The film was shot at 24 frames a second for image clarity from a low angle and is a complete record of the coastal zone as it existed in May, 1975. The ability to analyze the film frame by frame is especially important to delineate and assess coastal features, both natural and man-made, that are affecting relative rates of recession and erosion.

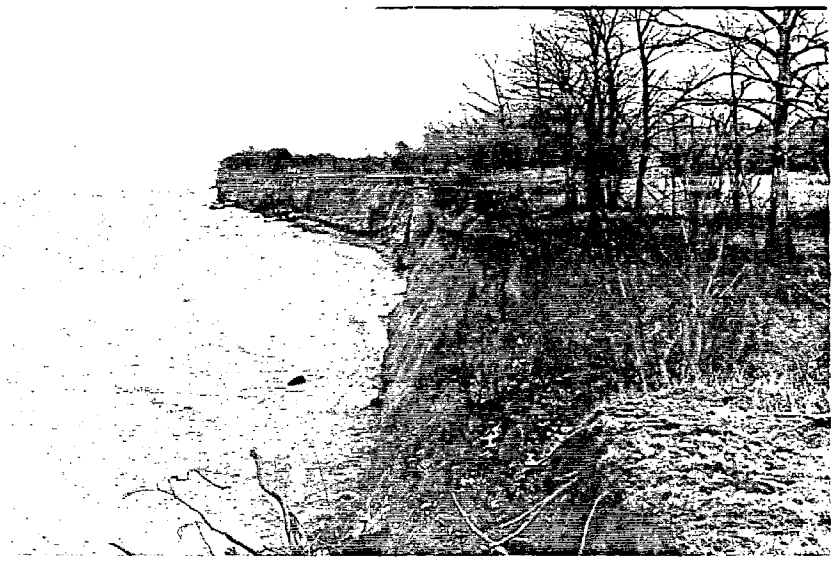
As a result of utilizing the three methods of field reconnaissance, we believe we have a definitive record of the coastal zone essential for critical hazard area assessment. We further believe that the collection of this information for use as a visual base will be essential for future study.

RESULTS OF FIELD RECONNAISSANCE

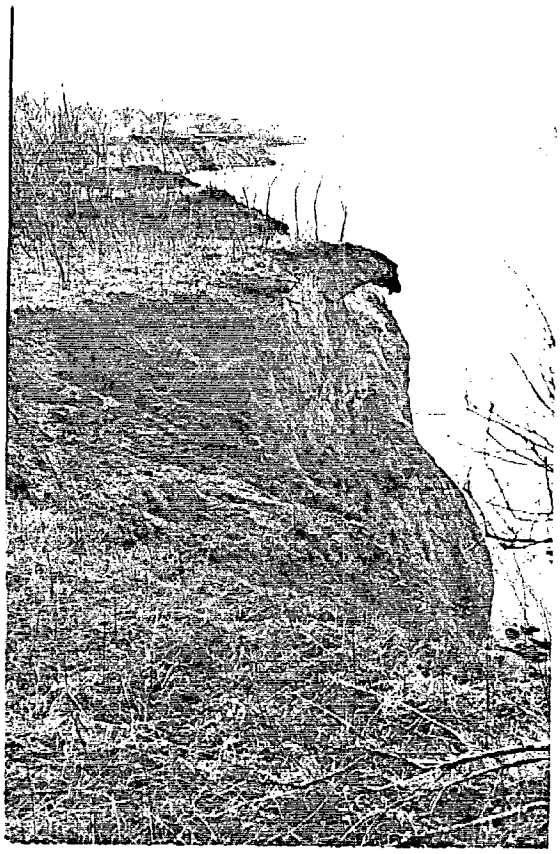
LOCATION:	Ohio Line to Rudd Road
TOWNSHIP:	Springfield
PLACE NAME IDENTIFICATION:	U. S. Steel Property
LONGSHORE DISTANCE:	1.5 miles
BLUFF HEIGHT:	Uniformly 50 ft. dipping to 10-20 ft. near Rudd Road
STRUCTURES SUBJECT TO DAMAGE:	29 cottages
CONTROL STRUCTURES:	None
SHORE ZONE DESCRIPTION:	Bluff is near vertical with recent rapid recession apparent. Narrow beach strands (2-3 ft.) during low water. Bluff crest usually grassy to edge with sod lap in erosion areas. Some trees on edge. Bluff face is essentially void of vegetation. Two unnamed tributaries east and west of Rudd Road have dissected the bluff and reduced land elevation to 10 to 20 ft.



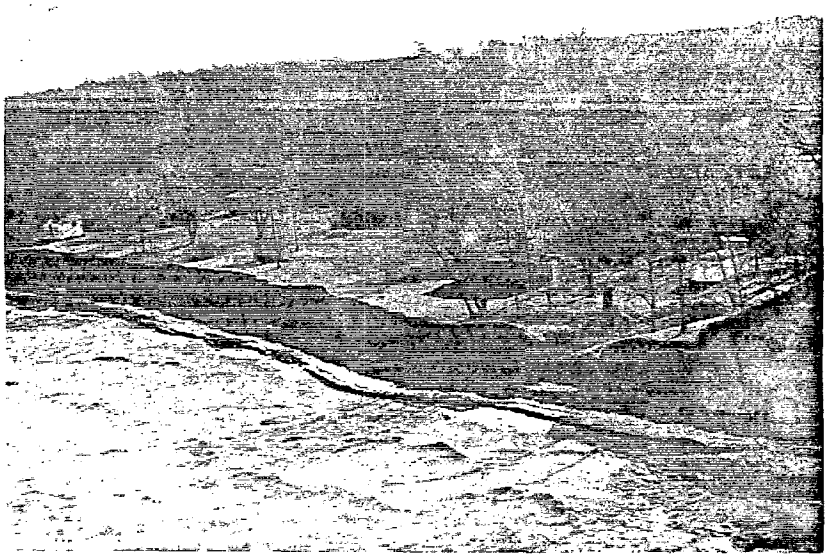
Above: Old Lake Road, Springfield Township between Ohio Line and Rudd Road



View looking east from near Ohio Line, Springfield Township

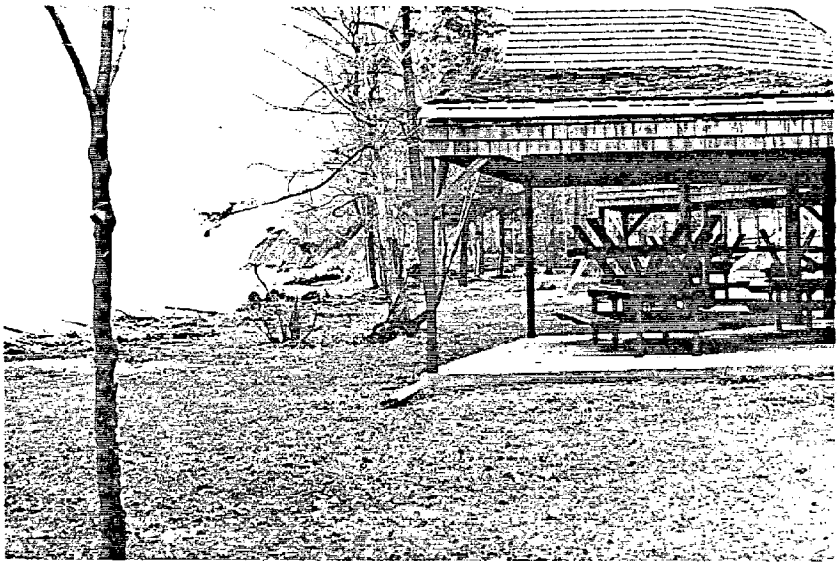


Above: View looking west toward Ohio Line, Springfield Township

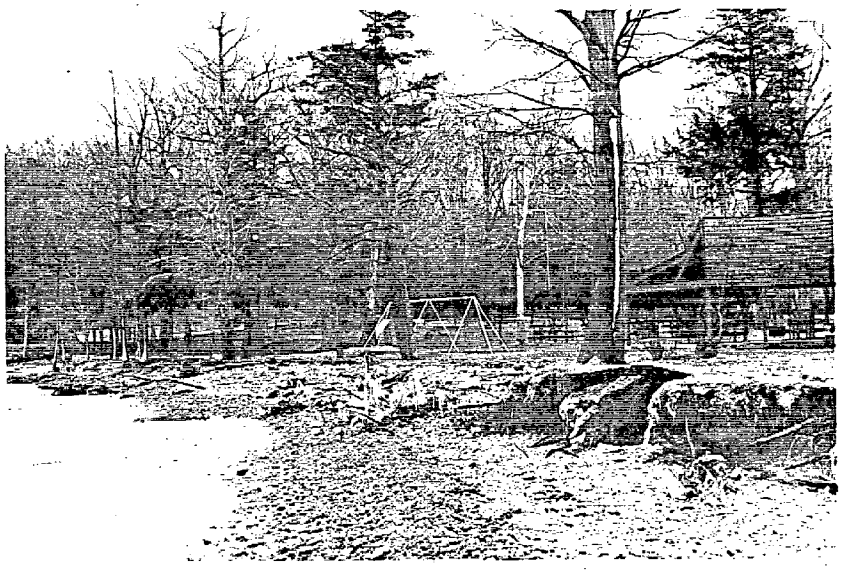


Above: At foot of Rudd Road looking east, Springfield Township

LOCATION:	Rudd Road to Elmwood Road
TOWNSHIP:	Springfield
PLACE NAME IDENTIFICATION:	
LONGSHORE DISTANCE:	0.6 mile
BLUFF HEIGHT:	15 ft. gradually rising to 60 ft. before Raccoon Creek
STRUCTURES SUBJECT TO DAMAGE:	4, plus 10 mobile homes and two picnic shelters
CONTROL STRUCTURES:	None (destroyed groin at Raccoon Creek)
SHORE ZONE DESCRIPTION:	Bluff is bare of vegetation and near vertical with erosion and recession evident. Several large slump blocks are visible on narrow beach strand. There is considerable vegetative disruption with sod lap and downed trees acting as temporary groins in several places. Severe beach erosion (20-30 ft.) in County Park within past eight months.



Above and below: Views of Raccoon Creek County Park, Springfield Township

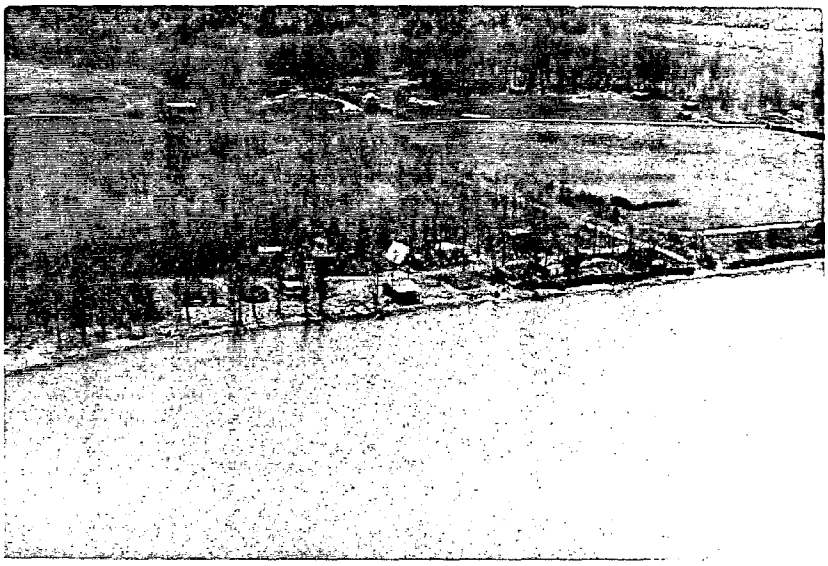


LOCATION:	Raccoon Creek to Ellis Road
TOWNSHIP:	Springfield
PLACE NAME IDENTIFICATION:	
LONGSHORE DISTANCE:	1.0 mile
BLUFF HEIGHT:	Irregular, varies between 40 to 70 feet
STRUCTURES SUBJECT TO DAMAGE:	2
CONTROL STRUCTURES:	None
SHORE ZONE DESCRIPTION:	Near vertical bluff; mass slumping evident. Grass and trees on bluff crest and slope are disrupted. Ground water is evident as a contributory factor in recession.

Above and below: Between Raccoon Creek and Ellis Road, Springfield Township

LOCATION:	Ellis Road to Eagley Road
TOWNSHIP:	Springfield
PLACE NAME IDENTIFICATION:	Summer City, Dunmar Estates, Eagley Road, Springfield Township Beach
LONGSHORE DISTANCE:	0.5 mile
BLUFF HEIGHT:	Variable, 10 to 40 ft.
STRUCTURES SUBJECT TO DAMAGE:	27 cottages
CONTROL STRUCTURES:	5 groins, 3 breakwalls (railroad ties, posts and rubber tires, cyclone fencing at individual cottages)
SHORE ZONE DESCRIPTION	Area is dissected by three main drainage divides. Bluff varies from vertical with rapid erosion and recession to gentle slopes subject to toe erosion and wave runup. Narrow beach strand in low water. Several cottages in critical danger on bluff edge. Makeshift breakwalls here suffered damage. Vegetation is spotty and disrupted. Recession has been caused by both ground water and wave action.

LOCATION:	Eagley Road to Holliday Road
TOWNSHIP:	Springfield
PLACE NAME IDENTIFICATION:	Camp Lambec, Dan's Beach, Camp Judson
LONGSHORE DISTANCE:	1.0 mile
BLUFF HEIGHT:	Irregular, 30-50 ft. at Camp Lambec, decreasing to 8-10 ft. at Camp Judson
STRUCTURES SUBJECT TO DAMAGE:	7 cottages and homes, plus 18 mobile homes
CONTROL STRUCTURES:	11 groins and 1 seawall
SHORE ZONE DESCRIPTION:	Low bluff, mostly vertical with little vegetation. Bedrock (1-3 ft. height) is briefly exposed. Camp Lambec, a private home, and Dan's Beach are protected by groin fields. Camp Judson is unprotected and is suffering rapid recession. Camp Judson has recorded 65 ft. of recession since 1970. Narrow beach strand (3-5 ft.) during low water.



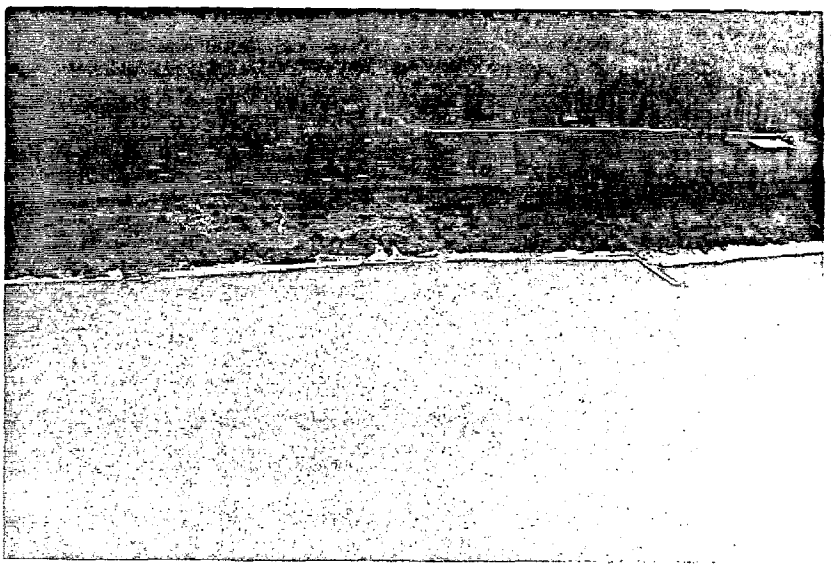
Above: Camp Judson and Holliday Shores, Springfield Township

Above: Holliday Shores, Springfield Township

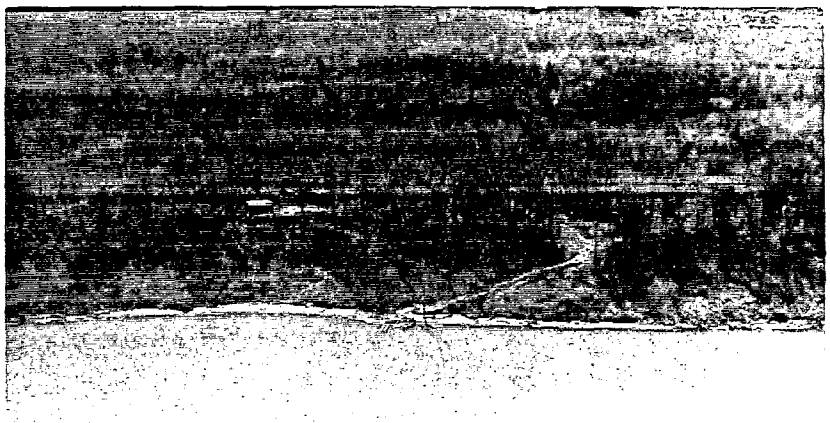
LOCATION:	Holliday Road to east of Crooked Creek
TOWNSHIP:	Springfield
PLACE NAME IDENTIFICATION:	Holliday Shores, Crooked Creek, Miles Beach
LONGSHORE DISTANCE:	0.4 mile
BLUFF HEIGHT:	Small bluff and rising lake plain 0-10 ft.
STRUCTURES SUBJECT TO DAMAGE:	27 cottages
CONTROL STRUCTURES:	None at Holliday Shores; 3 groins at Crooked Creek
SHORE ZONE DESCRIPTION:	Vertical bluff at Holliday Road subject to rapid recession; project team recorded 4 ft. recession from February to May, 1975. Practically all trees in beach zone have been washed away. Cottages have suffered flooding and damage from waves, ice, and toppled trees. At Crooked Creek, groins built since 1973 have built up beach and protected cottages.

Above: Damage to beach and structures at Holliday Shores

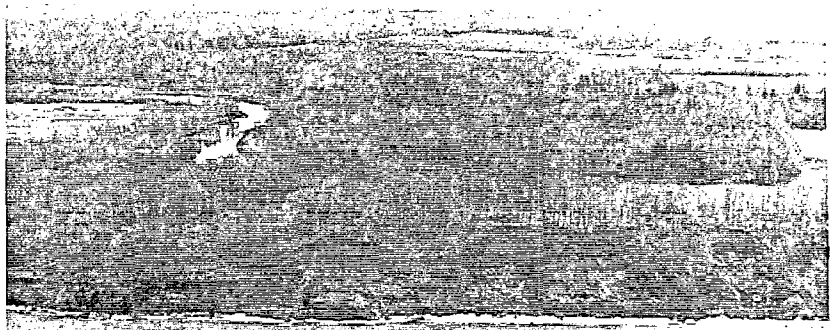
LOCATION:	Crooked Creek to Elk Creek
TOWNSHIP:	Springfield/Girard
PLACE NAME IDENTIFICATION:	Camp Fitch, Camp Sequoyah, Penelec Property
LONGSHORE DISTANCE:	3.4 miles
BLUFF HEIGHT:	Uniformly 80 ft. except rising 110 ft. at Elk Creek
STRUCTURES SUBJECT TO DAMAGE:	3
CONTROL STRUCTURES:	Camp Fitch - 3 groins; Camp Sequoyah - 1 groin
SHORE ZONE DESCRIPTION:	Bluffs in the camps are wooded, 70-80° slopes, and are relatively stable where the shore is protected by groins. The Fitch groins have created a large beach area. However, east of the groin field at Camp Fitch, rapid erosion and recession is occurring. From Camp Sequoyah to Elk Creek there is periodic evidence of erosion and recession. In places, the bluff face is covered with vegetation and trees. In other places, it is open and eroded. On the shore, fallen trees are serving as temporary groins. There is a narrow beach strand (5-10 ft.) during low water. At the Penelec site, there is evidence of erosion and recession. The bluff rises to 110 ft. at the site due to truncation of a former glacial beach ridge. When the Draft Environmental Impact Statement for the proposed power plant at the site was written in 1972, there was little concern for the recession problem. Recession was not expected to be a problem to be dealt with. However, higher water levels since 1972, apparent erosion and recession, and the planned construction of several portions of the plant close to the bluff crest, and the planned construction of intake and effluent pipes down to the shore zone make the problem of greater concern in 1975.



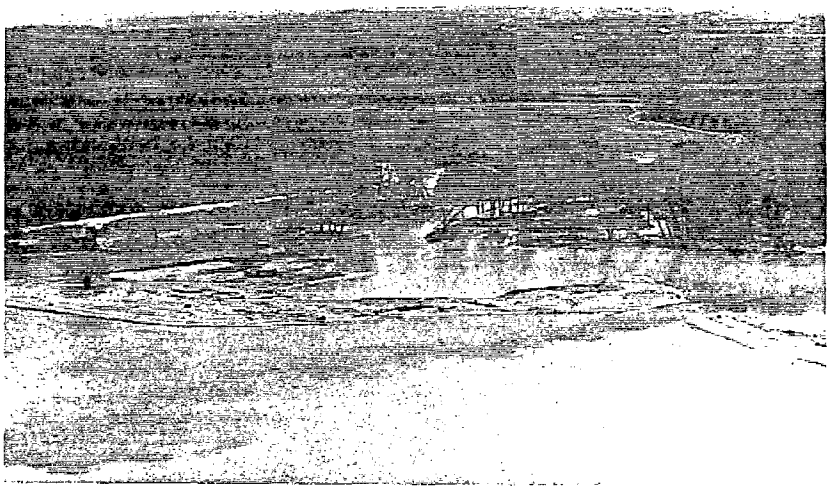
Above: Camp Fitch, Springfield Township: showing vegetation on bluff face west of groin and apparent rapid recession east of groin



Above: Camp Sequoyah, Springfield Township: showing toe erosion on right side of photograph and bluff recession directly below camp building

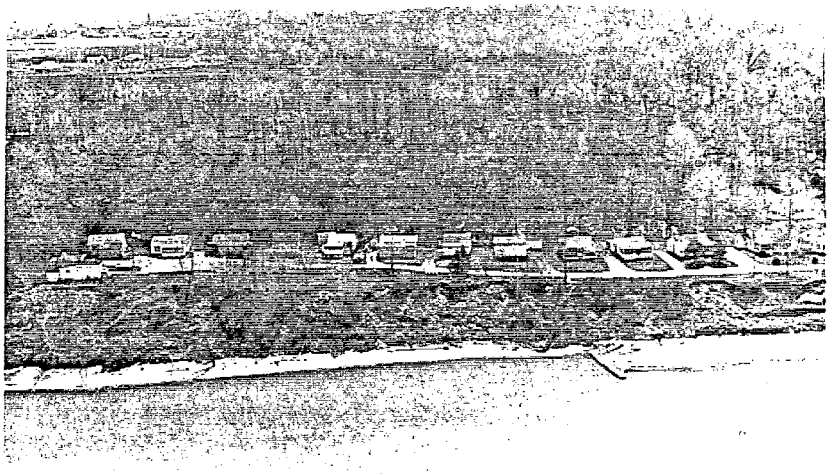


Above: Penelec site, Girard Township: showing evidence of erosion of bluff face



Above: Mouth of Elk Creek, Girard Township: showing flooding potential

LOCATION:	Elk Creek
TOWNSHIP:	Girard
PLACE NAME IDENTIFICATION:	
LONGSHORE DISTANCE:	0.5 mile
BLUFF HEIGHT:	Stream mouth-plain rising to 30 ft. terraced bluff
STRUCTURES SUBJECT TO DAMAGE:	10 subject to flooding; 6 subject to imminent recession; 20 cottages plus road subject to long term recession
CONTROL STRUCTURES:	2 groins plus several abandoned cars at base of bluff
SHORE ZONE DESCRIPTION:	The Mouth of Elk Creek is a broad, wide beach extremely vulnerable to lake flooding. East of the mouth (approximately 1,000 ft.) there is a 30 ft. terrace bluff in front of the 100 ft. main bluff. There is intense cottage development in this area which is in critical danger because of rapid recession due to both storm erosion and ground water drainage. Two groins east of the area and cars toppled over the bluff have started to build 10-20 ft. of beach during low water. However, ground water and storm driven waves still make the bluff very active. It is vertical in most places.



Above: Cottages on bluff terrace east of Elk Creek, Girard Township; showing bluff recession despite groins and sand accumulation

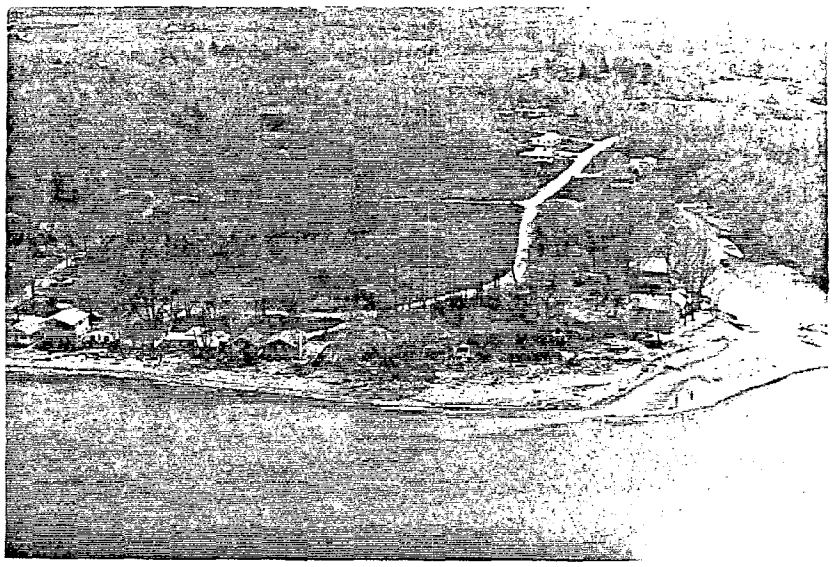
Above: Cottage overhanging bluff crest; view looking west toward mouth of Elk Creek, Girard Township; note abandoned cars at base of bluff

LOCATION:	Elk Creek to Culbertson Road
TOWNSHIP:	Girard
PLACE NAME IDENTIFICATION:	Fiesler Drive, Lake Erie Community Park, Richardson's Cement Works, Erie Lakelands Association
LONGSHORE DISTANCE:	1.4 miles
BLUFF HEIGHT:	Uniformly 110-120 ft. except two large stream cuts
STRUCTURES SUBJECT TO DAMAGE:	10
CONTROL STRUCTURES:	2 groins
SHORE ZONE DESCRIPTION:	The high bluffs with 60^{o} slope are generally stable from Elk Creek to Lake Erie Community Park. In the park there are two massive slump blocks on 80^{o} slopes which have been displaced downward to 10 ft. in the past two years. There are also several areas that have suffered rapid erosion and recession. This area is relatively unprotected with only a narrow beach strand during low water and occasional trees acting as temporary groins. The groin used by the cement works to collect sand and gravel has built up 25-50 ft. of beach and serves to protect and stabilize the eastern edge of the park. In the Lakelands area there is another large slump block similar to the ones in the park. There is periodic erosion interspersed with stable bluffs.

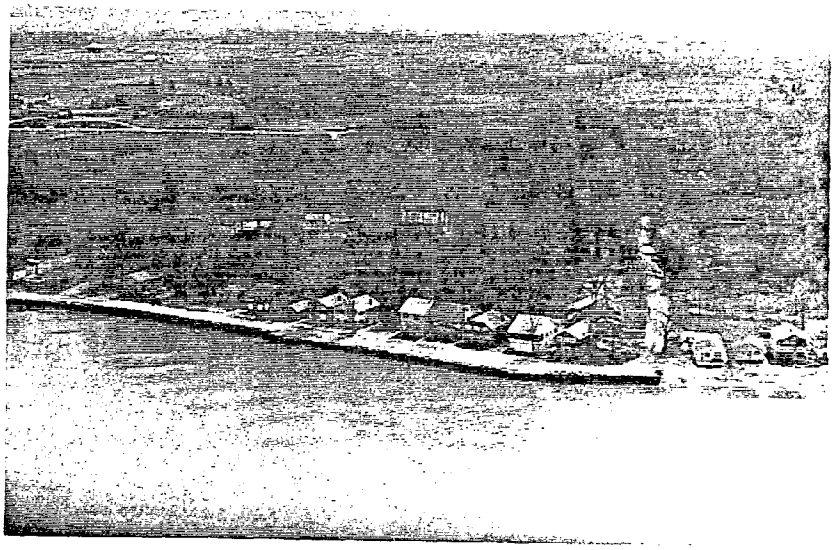
Above: Lake Erie Community Park, Girard Township showing area of mass wasting

Above: Lake Erie Community Park, Girard Township; showing vertical displacement of massive slump block

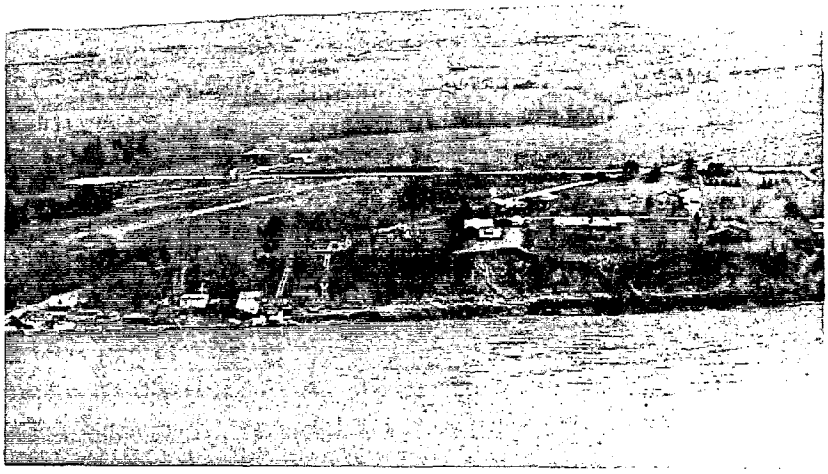
LOCATION:	Sixteen Mile Creek to New York State Line
TOWNSHIP:	North East
PLACE NAME IDENTIFICATION:	Sunset Beach, Orchard Beach, Francroft, Woodmere, Peck's Subdivision, Hidden Lane, Dewey Road Fish Commission Access Area, Twenty Mile Creek, Gay Road, St. Barnabas House
LONGSHORE DISTANCE:	4.0 miles
BLUFF HEIGHT:	Irregular, 10-50 ft. to Perdue Run, 10-30 ft. to State Line
CONTROL STRUCTURES:	Steel drum breakwall at Orchard Beach plus several individual breakwalls
SHORE ZONE DESCRIPTION:	This is a section of beaches and low terraced bluffs which is intensely developed for residential use, both permanent and summer. There is also some agricultural usage on top of bluffs. Bedrock is essentially absent in this section. There are sand and gravel deposits at most areas along the shore. At Sixteen Mile Creek, there is a broad delta which has formed a bay mouth bar which periodically causes flooding to several cottages at Sunset Beach. There has been severe damage in several places, especially to boathouses, cottages, and homes on the beach. In the Francroft-Woodmere section approximately a dozen structures on the beach have been destroyed in the past three years. Other areas have received varying degrees of damage, with protection only available from beaches 25-50 ft. to water's edge. There has been significant toe erosion in areas where low bluffs are near the water's edge.



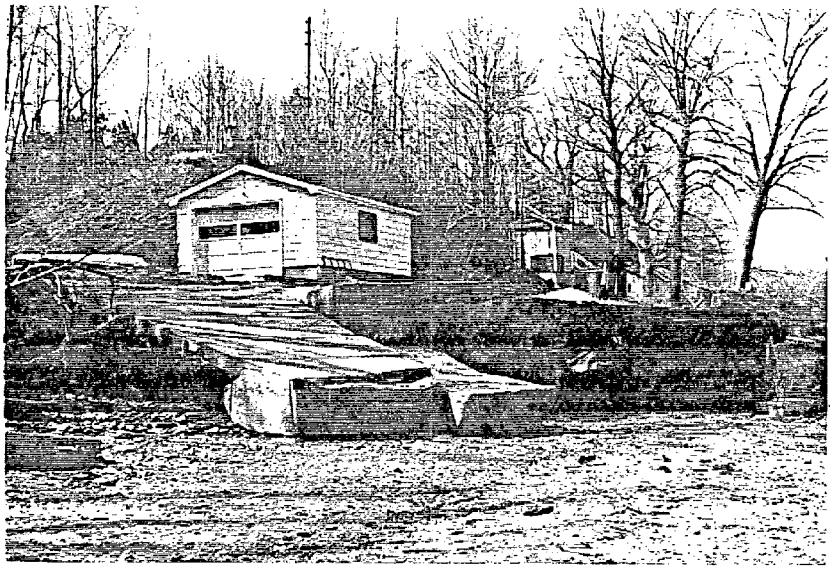
Above: Sunset Beach, Sixteen Mile Creek, North East Township; showing flood potential behind bay mouth bar



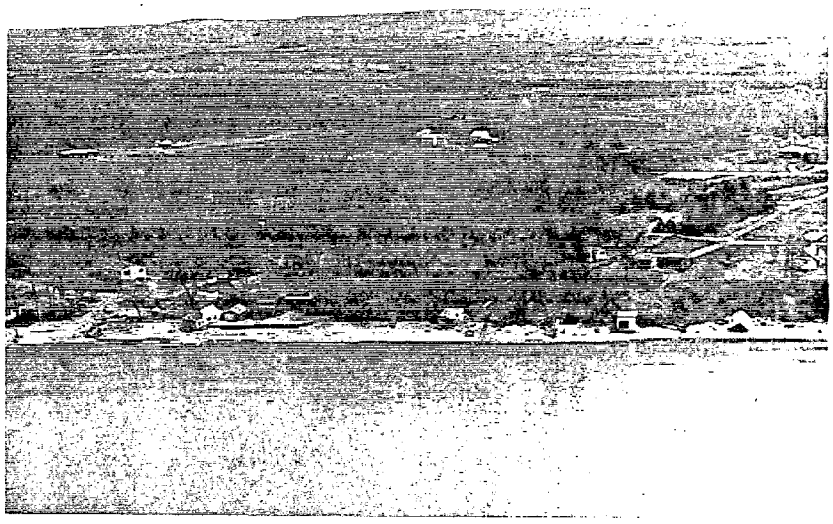
Above: Orchard Beach, east of Sixteen Mile Creek, North East Township; showing steel drum breakwall



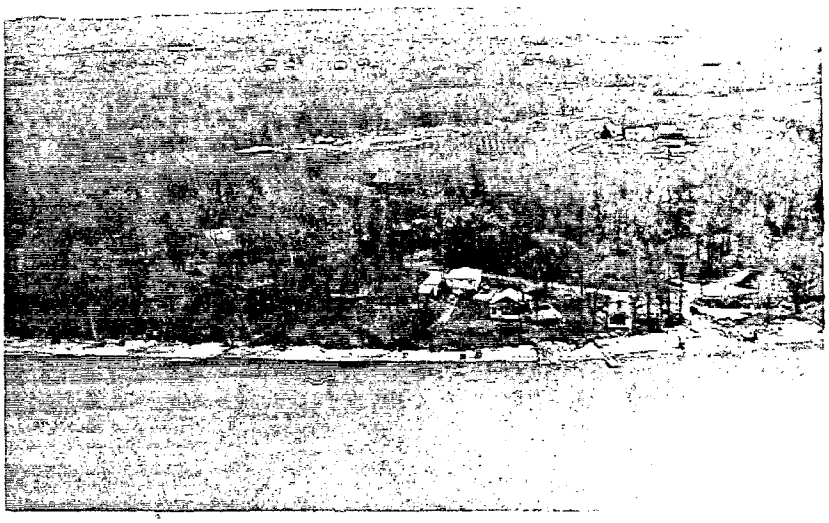
Above and below: Francroft Subdivision, North East Township; showing destruction of boat houses and beach cottages



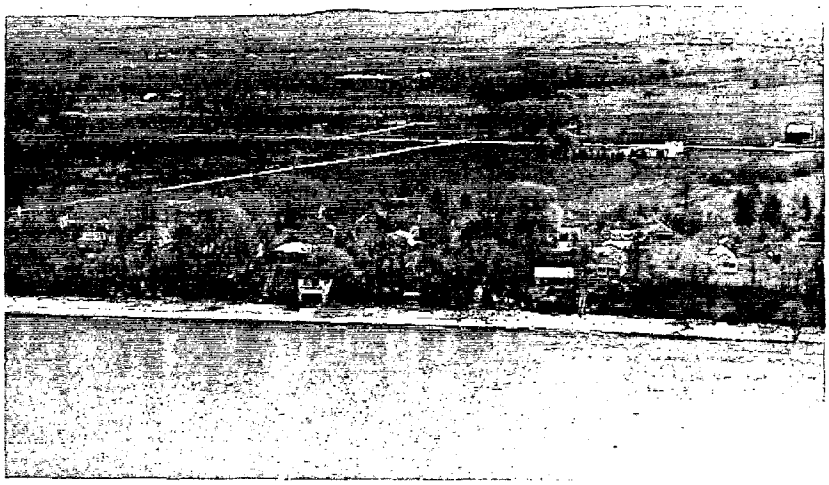
Above: Francroft Subdivision, North East Township; showing disrupted boat ramp



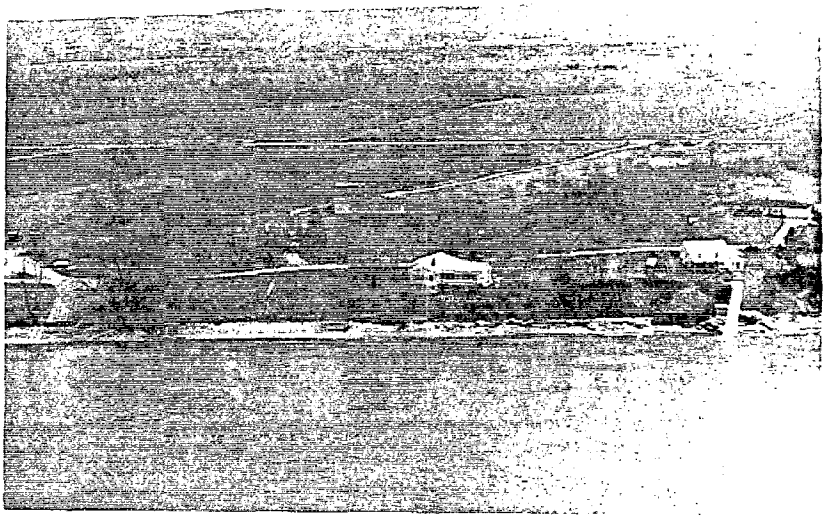
Above: Francroft and Woodmere areas, North East Township; showing destruction of beach cottages and boat houses



Above: Woodmere, North East Township



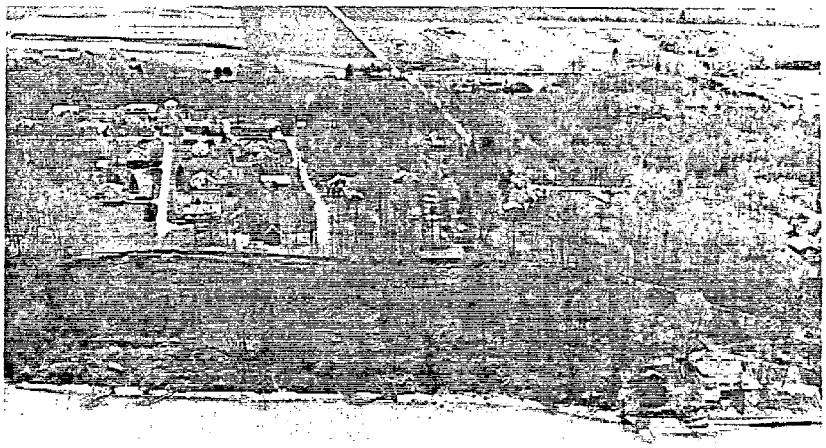
Above: Peck's Subdivision, North East Township



Above: Dewey Road, North East Township; showing disrupted Fish Commission boat access at far left of picture

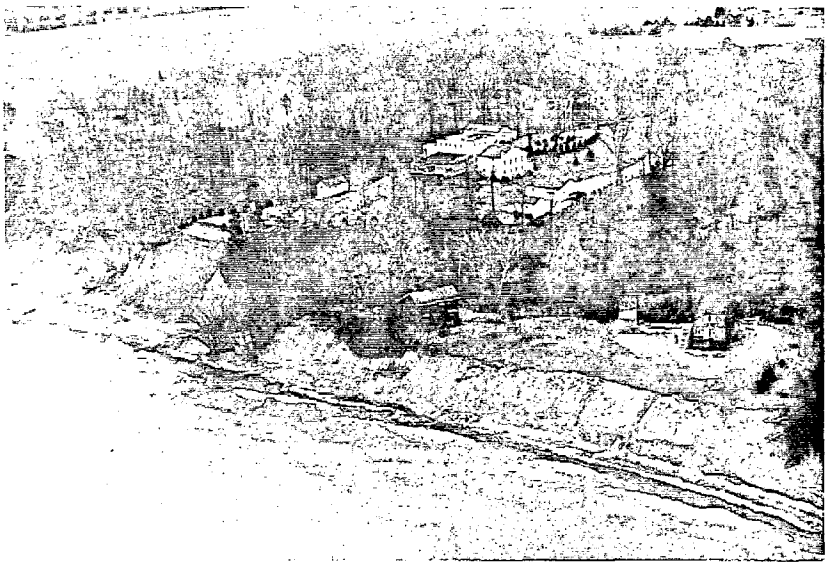
Above: Gay Road, North East Township

LOCATION:	Culbertson Road to Fairview Township line
TOWNSHIP:	Girard
PLACE NAME IDENTIFICATION:	Culbertson Road, Camp Eriez, Godfrey Road, Fairplain Road, Camp Sherwin
LONGSHORE DISTANCE:	2.3 miles
BLUFF HEIGHT:	Variable - 70-90 ft.
STRUCTURES SUBJECT TO DAMAGE:	30 (Mostly large cottages and permanent homes)
CONTROL STRUCTURES:	11 groins, 3 breakwalls, 1 destroyed breakwall
SHORE ZONE DESCRIPTION	This is a high bluff area except for two cottage areas on Culbertson Road and Godfrey Run, both 10 to 30 ft. terrace areas. There are two cottages in each area subject to imminent danger; however, they are protected for the short term by breakwalls and groins. In the absence of protective lake ice, these structures are subject to direct attack by storm-driven waves. Bluff slope varies from 60-80° with toe erosion, recession, and slumping at bluff crest periodically appearing. East of Culbertson Road, bedrock appears (3 to 5 ft. high). Most of the bluff crest has been cleared for residential or agricultural use. Ground water drainage has caused two areas of bluff crest slumping. There is a narrow beach strand during low water. Individual groins plus periodic bedrock protect some properties. However, there are also several homes near the bluff edge which are in danger if this protection is lost or if ground water seepage endangers the bluff crest.



Above: Vicinity of Culbertson Road, Girard Township; showing recent slumping at crest of bluff

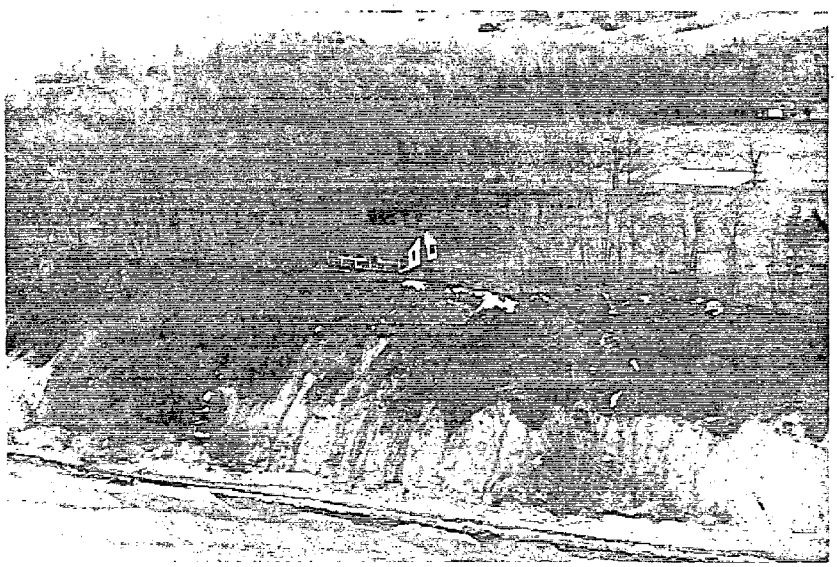
Above: Vicinity of Culbertson Road, Girard Township; showing two cottages in danger



Above: Godfrey Run, Fairplain Road, Girard Township; showing cottages in danger; there is also a cottage at base of bluff behind two trees

Above: Godfrey Run, Fairplain Road, Girard Township; showing cottage in danger on crest of bluff

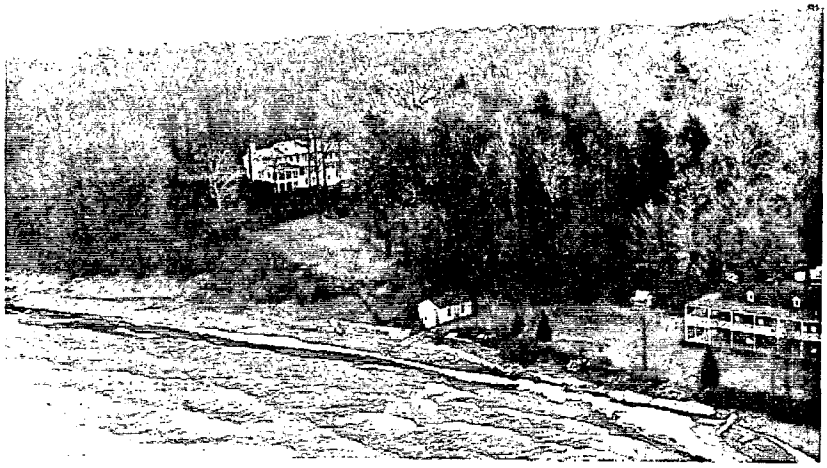
Above: Farm in Girard Township; showing toe erosion due to wave action and bluff crest recession due to ground water runoff



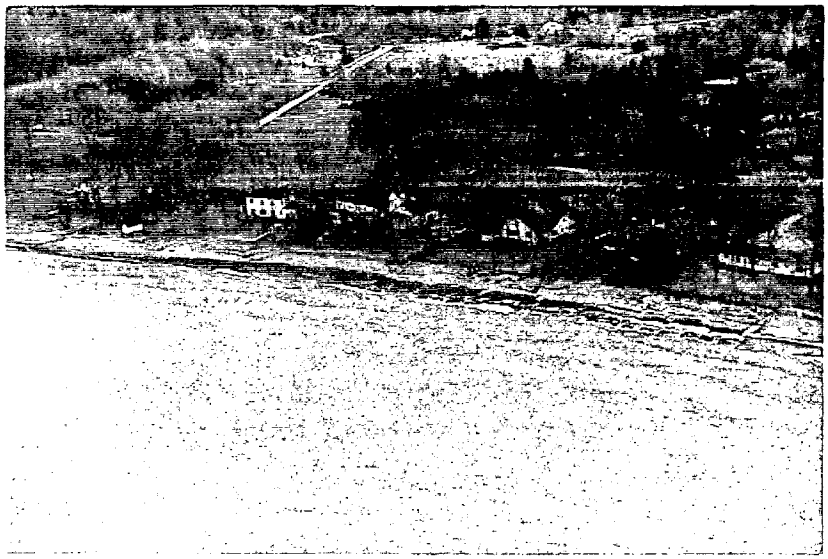
Above: Vicinity of Camp Sherwin, Girard Township; showing structure in danger

LOCATION:	Fairview Township line to Trout Run
TOWNSHIP:	Fairview
PLACE NAME IDENTIFICATION:	Hartley Road, Beach Drive, Melhorn Road, Erie Shores Association
LONGSHORE DISTANCE:	1.5 miles
BLUFF HEIGHT:	Uniformly 80 ft., except for three drainage cuts
STRUCTURES SUBJECT TO DAMAGE:	20 homes plus one swimming pool
CONTROL STRUCTURES:	The bluff area shows disrupted vegetation as evidence of periodic slumping due to ground water. There is also toe erosion in places which is changing the slope to near vertical. There is a narrow beach strand during low water and downed trees acting as temporary groins. Several beach cottages and boat houses in this section were destroyed in recent years.

LOCATION:	Trout Run to Walnut Creek
TOWNSHIP:	Fairview
PLACE NAME IDENTIFICATION:	Avonia Road, Lard Road, Eaton Road, Camp Notre Dame, Manchester Beach
LONGSHORE DISTANCE:	2.1 miles
BLUFF HEIGHT:	Variable 30-80 ft. descending to a 10 ft. lake plain at Manchester Beach
STRUCTURES SUBJECT TO DAMAGE:	28
CONTROL STRUCTURES:	9 groins and 1 seawall, plus Fish Commission channel groins at Walnut Creek
SHORE ZONE DESCRIPTION:	Bedrock appears, rising to 4-5 ft. high. In shore reaches unprotected by groins, there is active recession with slopes devoid of vegetation. Erosion at the toe of the bluff is disrupting vegetation up to the bluff crest. Ground water is also causing some slumping. Downed trees are acting as temporary groins in a few places. The private homes at Manchester Beach are protected by extensive beach deposits captures by the channel groins at Walnut Creek.

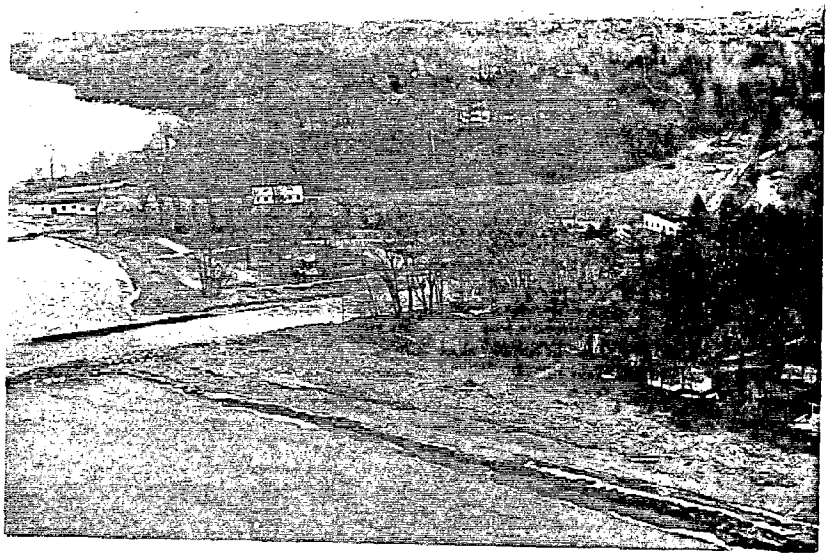


Above: Large homes east of Avonia Road, Fairview Township

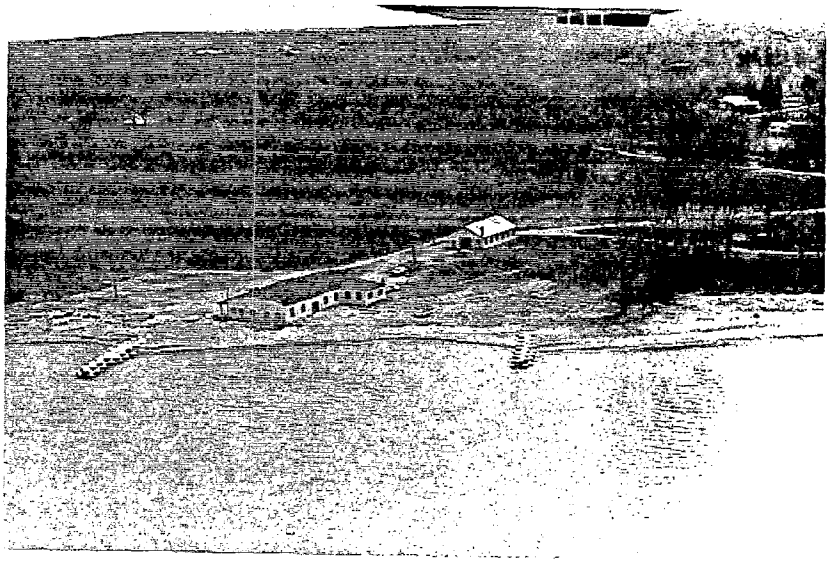


Above: Manchester Beach, Fairview Township

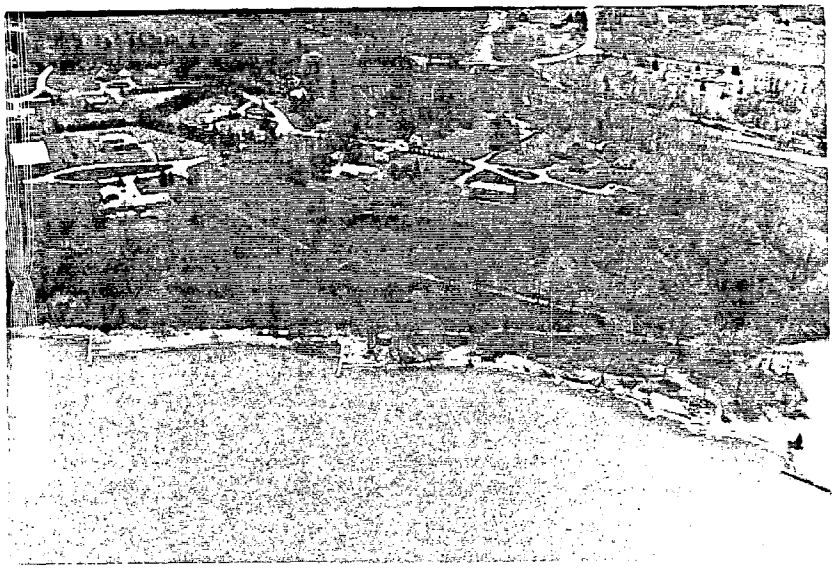
LOCATION:	Walnut Creek to Montpelier Avenue
TOWNSHIP:	Fairview/Millcreek
PLACE NAME IDENTIFICATION:	Walnut Creek Fish Commission Access Area, Manchester Heights, Lake Shore District, Lake Shore Country Club, Colony Subdivision, Wilkins Run, Wolf Road, Scott Estate
LONGSHORE DISTANCE:	3.3 miles
BLUFF HEIGHT:	Uniform 90-100 ft. except two main drainage cuts and several smaller access cuts.
STRUCTURES SUBJECT TO DAMAGE:	38, plus one swimming pool
CONTROL STRUCTURES:	4 groins at Walnut Creek plus 11 private groins and one seawall
SHORE ZONE DESCRIPTION:	The Walnut Creek Fish Commission Access Area has experienced severe beach erosion east of the stream mouth which is endangering the Fish Commission building on the shore. Immediately east of the stream delta, the bluff rises to 90 ft. Bedrock appears in the Lake Shore District and continues to Montpelier Avenue in heights from 5 to 15 ft. Eleven private groins and a large number of downed trees provide some sand accumulation at the base of the bluff; otherwise, there is not beach. There is periodic disruption of the vegetation on the bluff, which varies from 60 to 90° slope. There is active slumping and material flow in several areas, including a large slump measuring approximately 150 ft. long and 30 ft. wide. The bluff is alternately stable or active depending on groin protection, ground water drainage, and vegetative cover.



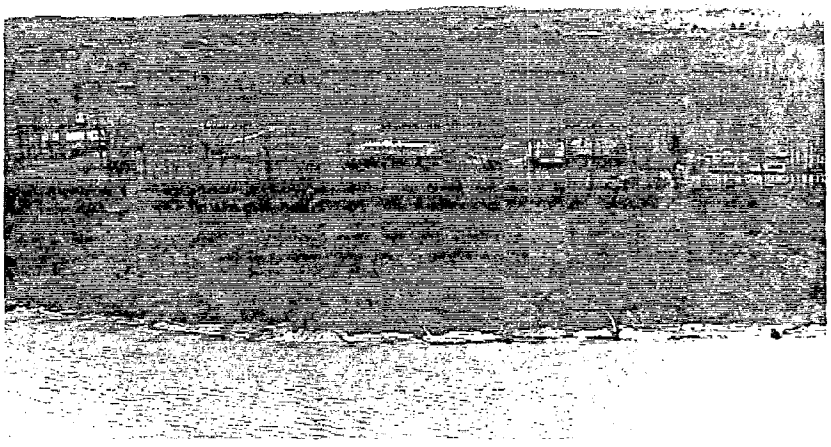
Above: Mouth of Walnut Creek, Fairview Township; showing Fish Commission Access Area east of stream mouth



Above: Walnut Creek Fish Commission Access Area, Fairview Township

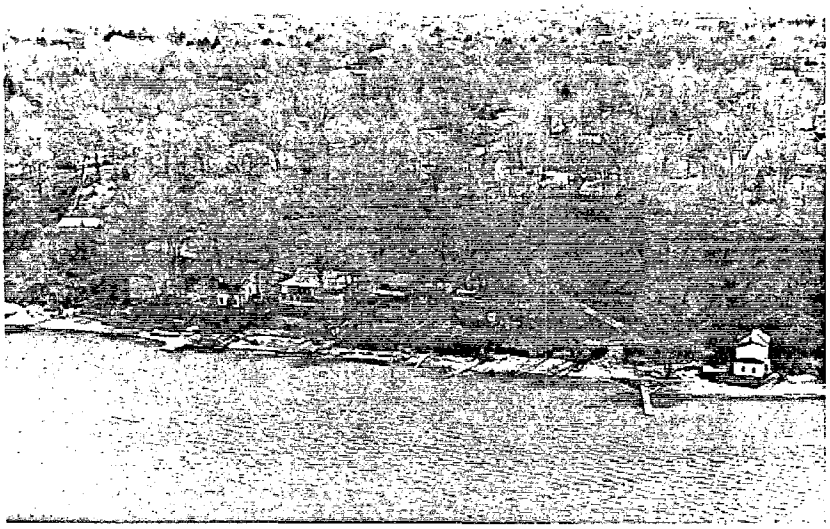


Above: Manchester Heights, Fairview Township; showing stable bluff due to groin protection and vegetation on bluff

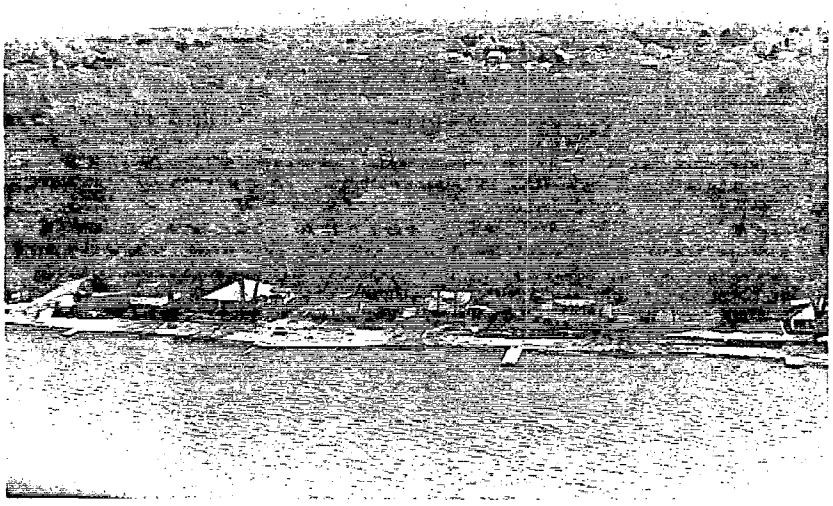


Above: Lake Shore District, Fairview Township; showing stable bluff with toe erosion beginning

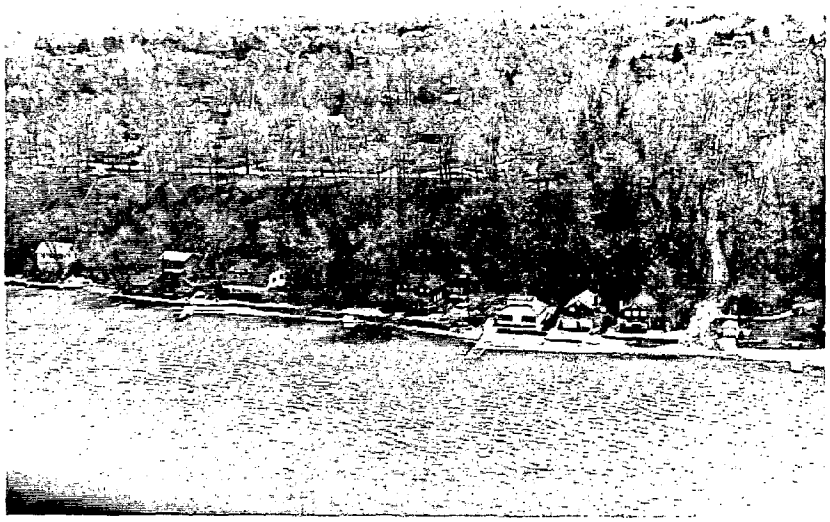
LOCATION:	Montpelier Avenue to neck to Presque Isle Peninsula
TOWNSHIP:	Millcreek
PLACE NAME IDENTIFICATION:	Hartt Estates, Glenruadh (The Willows) Eaglehurst, Forest Park, Baer Beach, Kelso Beach Hotel, Kelso Beach, Beachcomber Cottages, The Mark Restaurant
LONGSHORE DISTANCE:	1.6 miles
BLUFF HEIGHT:	Uniform 90 ft. except for 6 drainage cuts; beach and terrace bluffs 0-15 ft. high
STRUCTURES SUBJECT TO DAMAGE:	90 cottages
CONTROL STRUCTURES:	18 groins, plus 25-30 individual breakwalls and one buried breakwall at Beachcomber cottage area
SHORE ZONE DESCRIPTION:	The bluff, with a 60-80° slope, is essentially stable, well-covered with vegetation, and protected by beach and cottage development at the base of the bluff. There are, however, several places suffering slumping, soil creep, and toe erosion due to ground water seepage and wave action where the beach is totally submerged. Bedrock appears briefly in one section near the foot of Ardmore Avenue, rising to 8-10 ft. high. The significant activity in this section is related to the extensive cottage development on the beach below the bluff. There are several cottage areas on narrow beaches and low bluff terraces which are in continuing danger from flooding and erosion. Since 1972, the area from Hartt Estates to Baer Beach has suffered extensive beach erosion, flooding and storm damage to cottages and breakwalls. Approximately one dozen cottages in this area were completely destroyed as a result of storm. The cottages remaining have suffered varying degrees of damage from slight to extensive. There has been significant beach erosion. Makeshift breakwalls and groins have also been subject to storm damage. The Kelso Beach cottages have been relatively free from damage because of extensive beaches built by a groin. The Beachcomber cottages are somewhat protected by a beach ridge stabilized by a now-buried breakwall and the beginnings of the Presque Isle beach system. However, this area is subject to flooding during storms.



Above: Hartt Estates, Montpelier Avenue, Millcreek Township; showing cottages at base of bluff

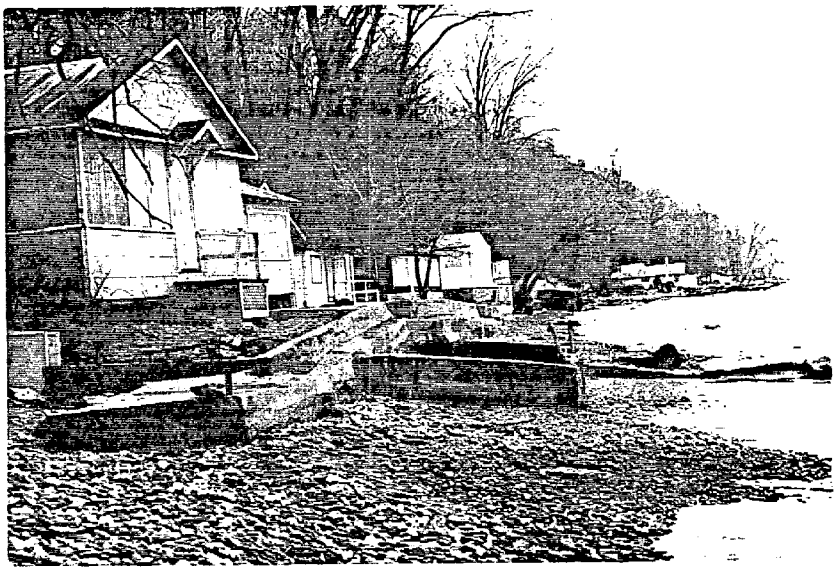


Above: Glenruadh (The Willows), west of Powell Avenue Millcreek Township

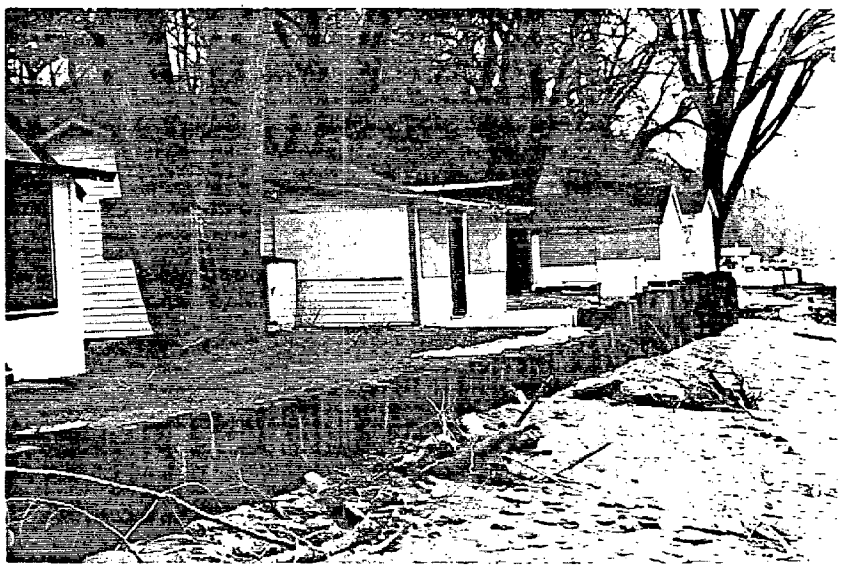


Above: Glenruadh section, east of Powell Avenue, Millcreek Township; showing cottages at base of bluff

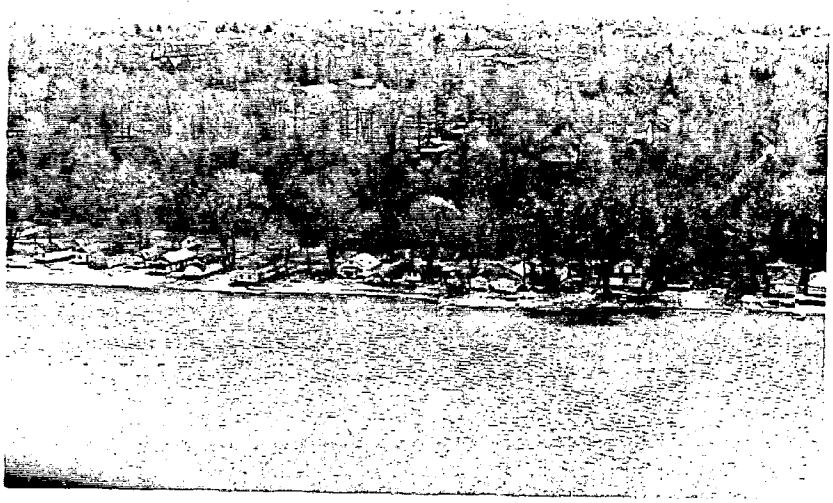
Above: East end of Glenruadh section, looking east toward Eaglehurst, Millcreek Township



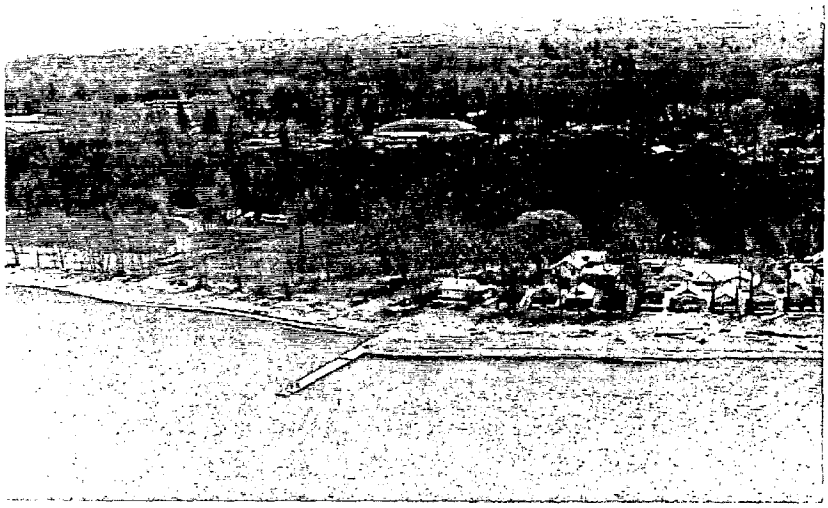
Above: View looking west toward Forest Park and Eagle-hurst, Millcreek Township



Above: Baer Beach Cottages, Millcreek Township



Above: Baer Beach, Millcreek Township

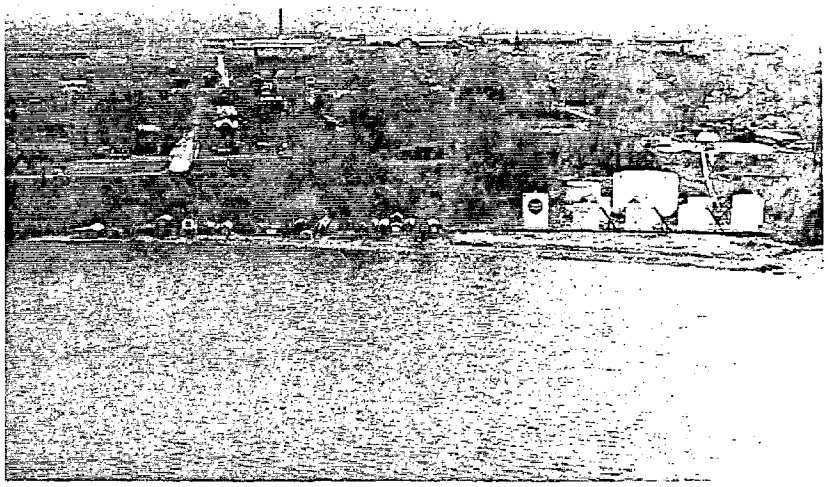


Above: Kelso Beach, Millcreek Township; showing beach protection created by groin

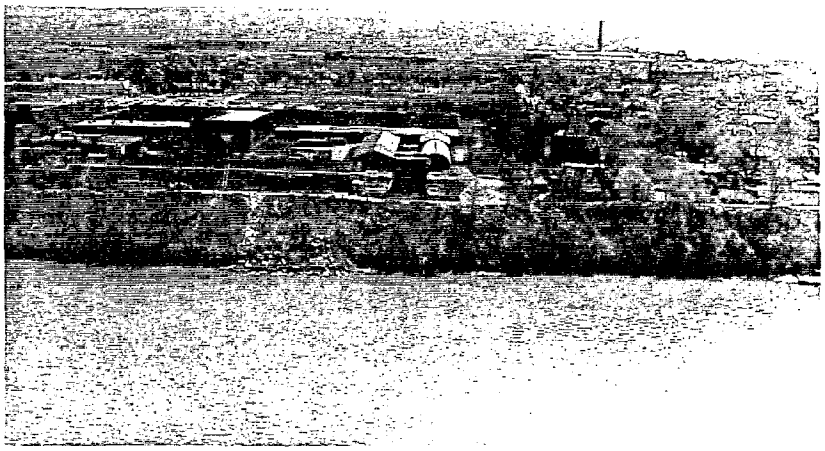
LOCATION:	Presque Isle Neck to Cascade Street
TOWNSHIP:	Millcreek - Erie Bayshore
PLACE NAME IDENTIFICATION:	Scott-Algeria County Park, Sommerheim Pumping Station, South Shore Drive, Erie Yacht Club
LONGSHORE DISTANCE:	2.3 miles
BLUFF HEIGHT:	Uniform 70-90 ft., except for three large cuts
STRUCTURES SUBJECT TO DAMAGE:	4 areas: Sommerheim, Yacht Club, Ferncliff Beach cottages, Cascade Creek cottages
CONTROL STRUCTURES:	3 breakwalls at Sommerheim, Yacht Club, and the Strong Estate (west of Cascade Creek)
SHORE ZONE DESCRIPTION:	The bluff is fairly stable, covered with vegetation and sloped at 60 and 80°. There is a drainage cut at the foot of Pittsburgh Avenue which is experiencing headward erosion. The area is fairly well protected by Presque Isle. Flooding of structures on the shore is the main danger in this area; however, seawalls provide protection.

LOCATION:	Cascade Street to Wayne Street
TOWNSHIP:	City of Erie Bayshore
PLACE NAME IDENTIFICATION:	Cascade Docks, Chestnut Street Pumping Station, Public Dock, Grain Elevators, Sewage Treatment Plant, Marine Terminal
LONGSHORE DISTANCE:	2.5 miles
BLUFF HEIGHT:	70 ft., decreasing gradually to 30 feet at Wayne Street
STRUCTURES SUBJECT TO DAMAGE:	13 major industrial and commercial areas
CONTROL STRUCTURES:	12 major docks and breakwall systems
SHORE ZONE DESCRIPTION:	The bluff is stable, covered with vegetation, at a 60-70° slope, and well removed from the shoreline. At the shore, there are extensive docks and artificial fill areas which are used mainly for industrial and commercial purposes. The main hazard is flooding due to high water and storm driven waves, principally in the Public Dock area. Additional study is needed to determine the effect of the proposed Bayfront Highway on the stability of this area.

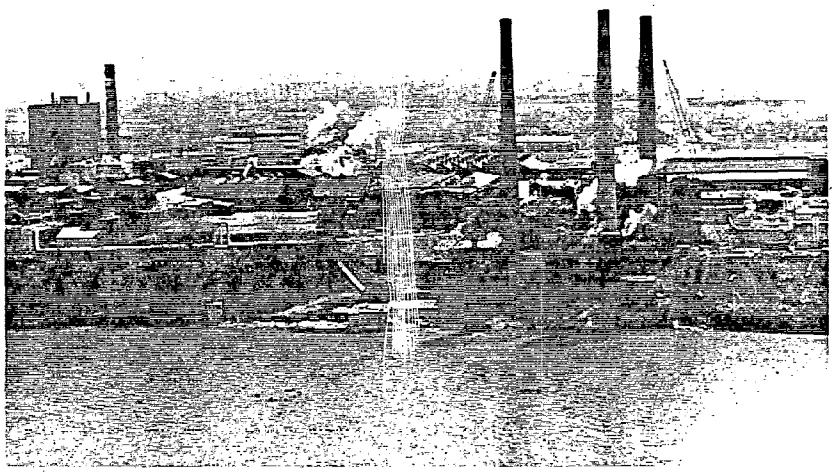
LOCATION:	South Pier to Dunn Blvd.
TOWNSHIP:	City of Erie
PLACE NAME IDENTIFICATION:	Koppers Coke Plant, Proposed Diked Disposal Area, East Avenue Boat Ramp, Gulf Oil Tanks, Port Authority boathouses
LONGSHORE DISTANCE:	1.1 miles
BLUFF HEIGHT:	0-10 ft. artificial fill and beach area
STRUCTURES SUBJECT TO DAMAGE:	Approximately 20 boathouses and 11 oil tanks
CONTROL STRUCTURES:	One small breakwall at East Avenue Boat Ramp One large breakwall around Gulf Oil Tanks
SHORE ZONE DESCRIPTION	This is a low-lying industrial and recreational area which is protected from the west and northwest by Presque Isle. The area will receive further protection when the proposed diked disposal area is constructed from the South Pier adjacent to the Koppers plant which is planned by the Corps of Engineers for the latter 1970's. The Erie Port Authority owns the shoreline containing the boat ramp and boat houses. This area is subject to flooding and erosion by storms from the north and northeast. Several of the boathouses have been damaged. The Port Authority hopes to further develop the area for recreational boating.



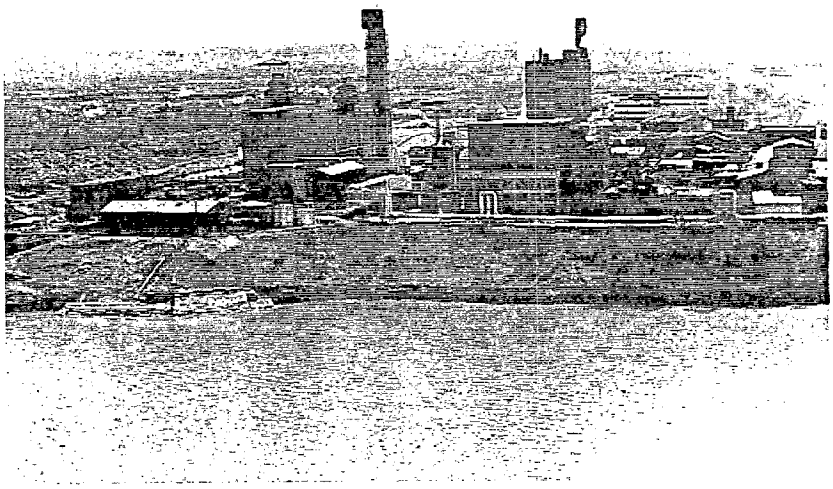
Above: Gulf Oil Tanks and boat houses, foot of East Avenue, City of Erie



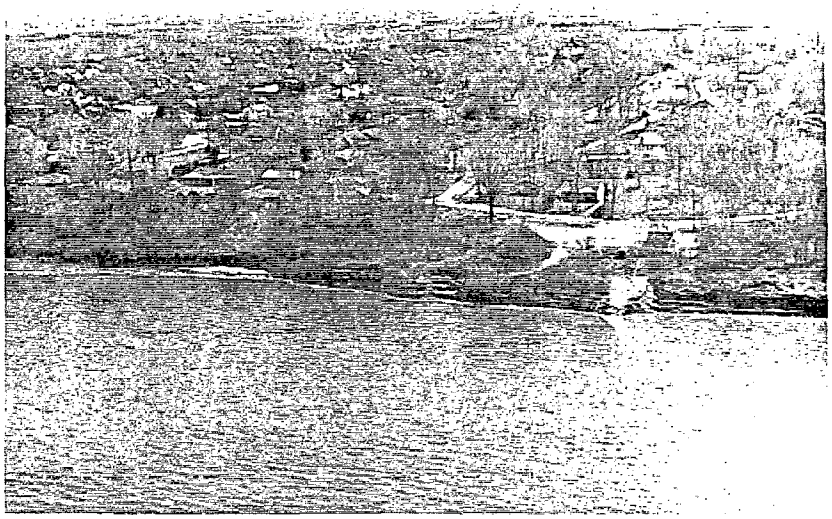
Above: Foot of Hess Avenue, City of Erie, showing west end of Hammermill Paper Company facilities



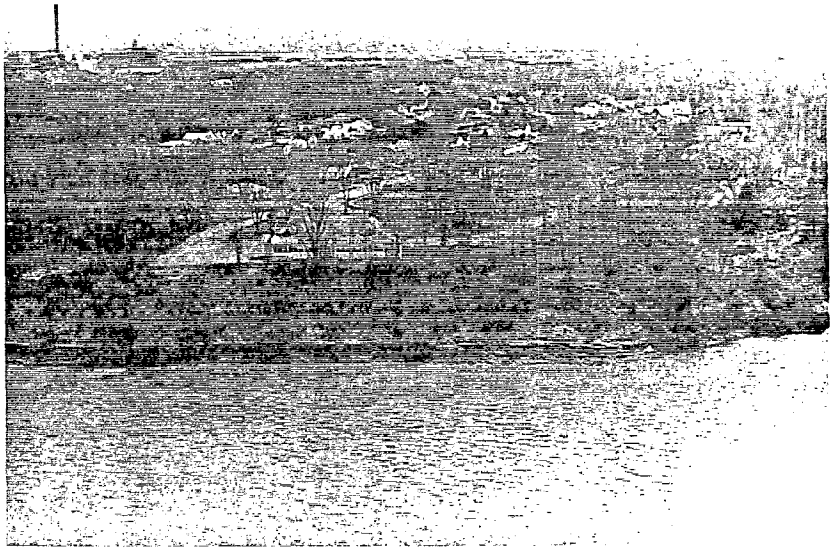
Above and below: Hammermill Paper Company facilities, City of Erie



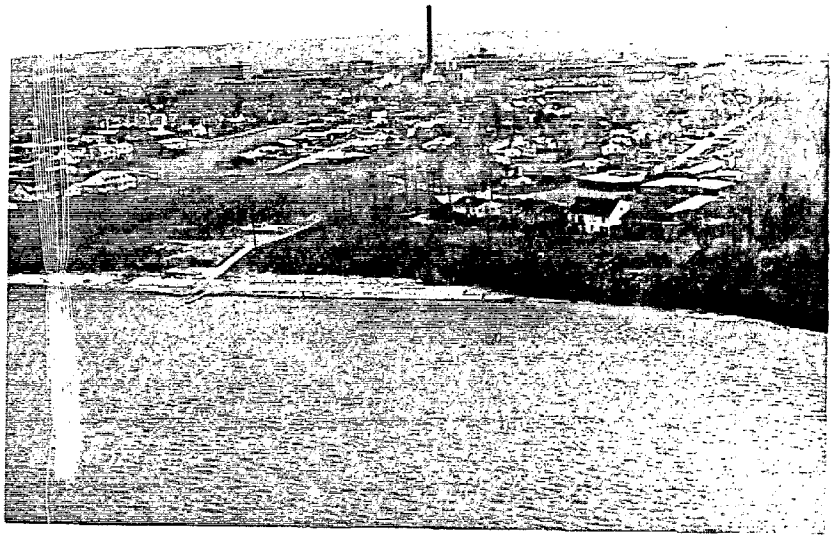
LOCATION:	Lighthouse Street to Harborcreek Township line
TOWNSHIP:	City of Erie and Lawrence Park Township
PLACE NAME IDENTIFICATION:	Lighthouse Park, Hammermill Paper Company, Lakeside Cemetery, Lakeside Drive, Sunset Inn, Lawrence Park Boat Dock, G. E. Fishing Club, Lawrence Park Golf Club
LONGSHORE DISTANCE:	2.4 miles
BLUFF HEIGHT:	Variable 20-60 ft. with 5 drainage cuts
STRUCTURES SUBJECT TO DAMAGE:	42 private homes plus Hammermill facilities and G. E. Fishing Club Boat house
CONTROL STRUCTURES:	5 Hammermill Breakwalls and Lawrence Park Boat Dock
SHORE ZONE DESCRIPTION:	Bedrock appears at Lighthouse Street and is continuous, except at Four Mile Creek, throughout the section at heights from 5-15 ft. Presque Isle provides some protection for this section from west and northwest storms. Historically, this section has been relatively stable due to the protection of Presque Isle and the bedrock. Most damage that occurred resulted from ground water seepage. Hammermill Paper Company has experienced hazardous conditions since 1967 and has spent $135,000 in four separate projects to protect its facilities since 1968. The company also constructed an outfall pipe in 1971 that is protected by massive sandstone rip rap. The bluff varies from 60-90° in slope. There are a few areas that have experienced mass wasting due to ground water and residential disturbance on the Erie portion of Lakeside Drive. Higher water levels and lack of ice cover have caused recession to accelerate in the past two years due to wave run up and spray on the bluff. Trees and houses on top of 40 ft. bluffs have been covered with 2 inches of frozen spray.



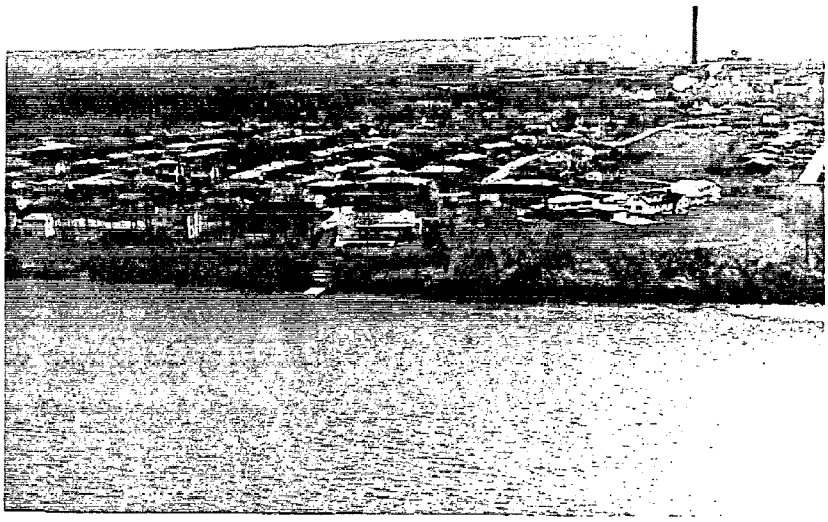
Above: Lakeside Drive, City of Erie; showing bedrock at base of bluff



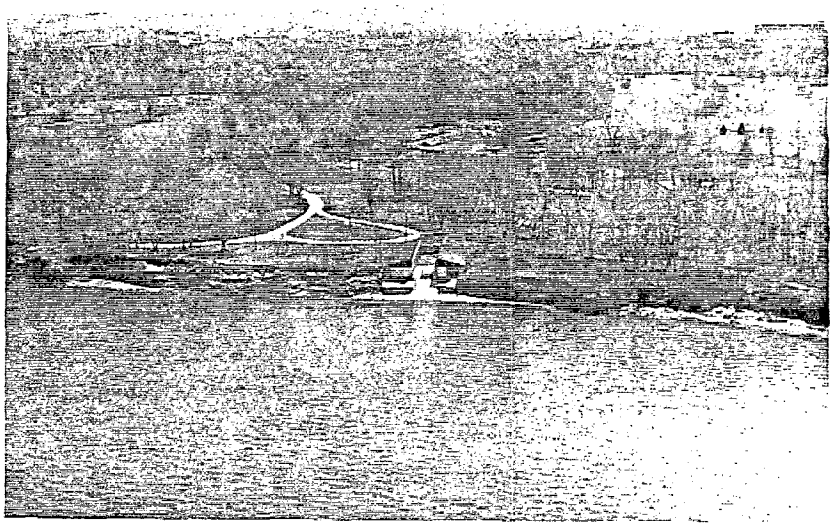
Above: Lakeside Drive, City of Erie; showing Sunset Inn on crest of bluff



Above: Lakeside Drive, Lawrence Park Township; showing public boat ramp and dock



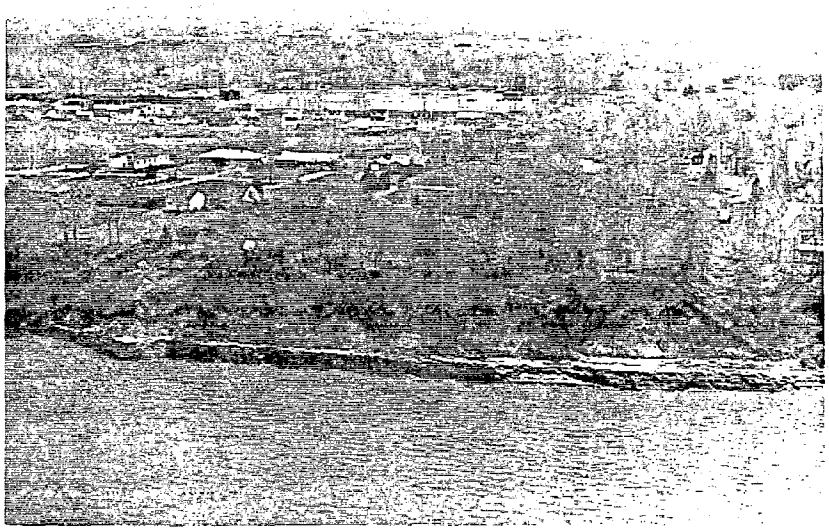
Above: Lakeside Drive, Lawrence Park Township



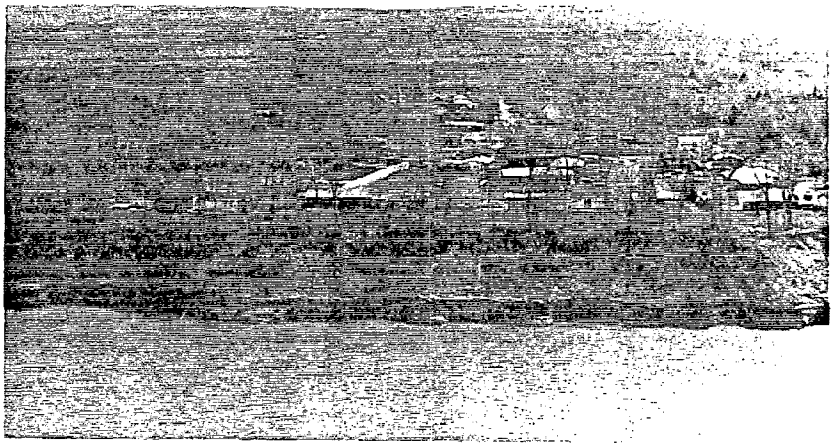
Above: General Electric Fishing Club, Lawrence Park Township

Above: Lawrence Park Golf Club, Lawrence Park Township; showing differential recession rates causing scalloped shoreline

LOCATION:	Harborcreek Line to Six Mile Creek
TOWNSHIP:	Harborcreek
PLACE NAME IDENTIFICATION:	Gunnison Park, South Shore Estates, Mobil Oil Tanks, Fairfield, Conrad House
LONGSHORE DISTANCE:	2.2 miles
BLUFF HEIGHT:	Irregular, 20-50 ft. to Fairfield, rising to 70 ft. at Conrad House, and decreasing gradually to 10 ft.
STRUCTURES SUBJECT TO DAMAGE:	37, including Conrad House
CONTROL STRUCTURES:	None
SHORE ZONE DESCRIPTION:	Bluffs are 70-90° in slope, with exposed bedrock forming one-fourth to one-half and more of total bluff height. Extremely irregular height of bluff is due to truncation and erosion of glacial deposits. This section, and the next section east, exhibit deep scalloping of the exposed bedrock, a phenomenon not otherwise seen on the Erie County shoreline. There is essentially no beach except near the mouth of Six Mile Creek. Bluff recession has accelerated the past two years due to lack of ice cover. The lower sections of bluff are then exposed to direct wave action and the overburden is easily eroded.

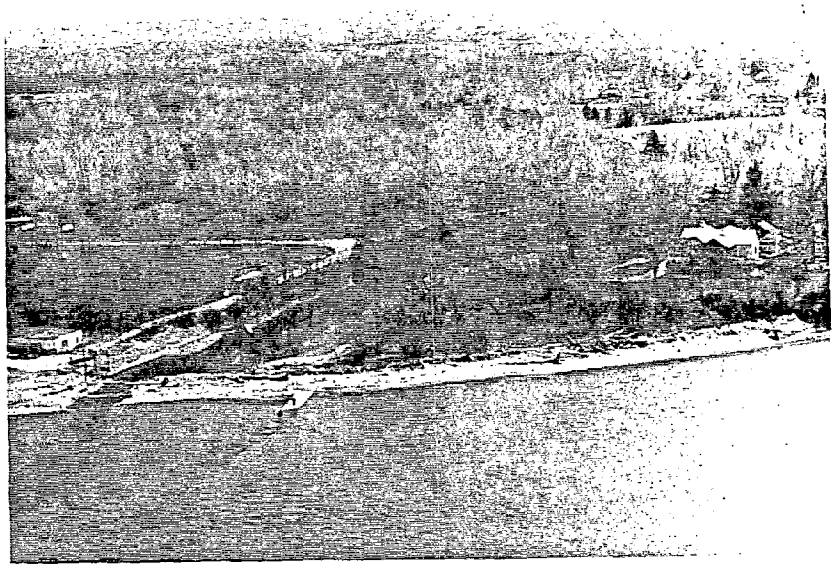


Above: Gunnison Park - South Shores Estates, Harborcreek Township

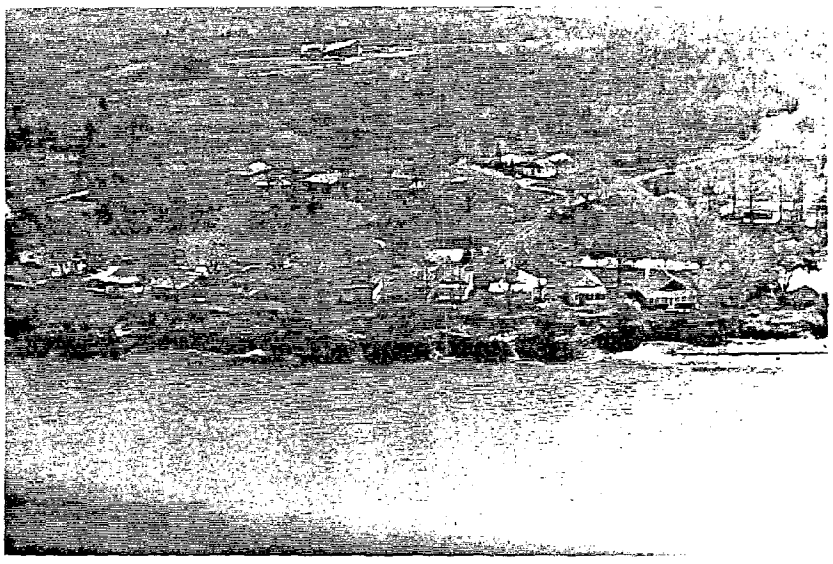


Above: Cambridge Road - Northview Drive, west of Six Mile Creek, Harborcreek Township; showing scalloping of bedrock

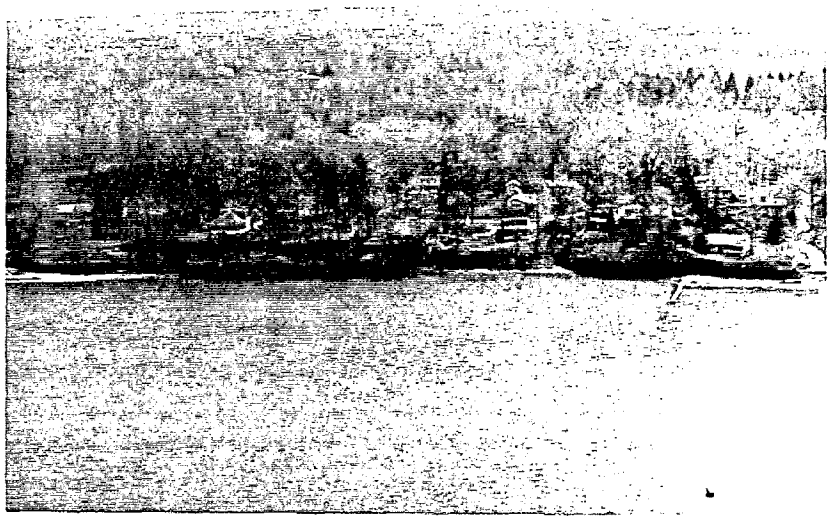
LOCATION:	Six Mile Creek to Eight Mile Creek
TOWNSHIP:	Harborcreek
PLACE NAME IDENTIFICATION:	Cowell's Beach, Carter's Beach, Seven Mile Creek, Camp Glinodo, Shade's Beach County Park
LONGSHORE DISTANCE:	1.4 miles
BLUFF HEIGHT:	Variable, 10-20 ft., past Camp Glinodo Rising to 70 ft. before Shades Beach
STRUCTURES SUBJECT TO DAMAGE:	30 cottages plus one swimming pool and a light industrial facility; also a large boathouse at Shade's Beach
CONTROL STRUCTURES:	4 groins, 1 breakwall, 2 boat docks
SHORE ZONE DESCRIPTION:	Bedrock decreases to 4-6 ft. Bluff is near vertical and is experiencing serious recession over entire section. Most cottages are near the bluff crest and are in imminent danger with only limited protection offered by control structures and bedrock. Very narrow low-water beach strand exists in some areas. Bluff vegetation is sporadic. Glacial erratics appear. The Shades Beach groin maintains a beach up to 50 ft. in depth which protects a public boathouse in the county park.



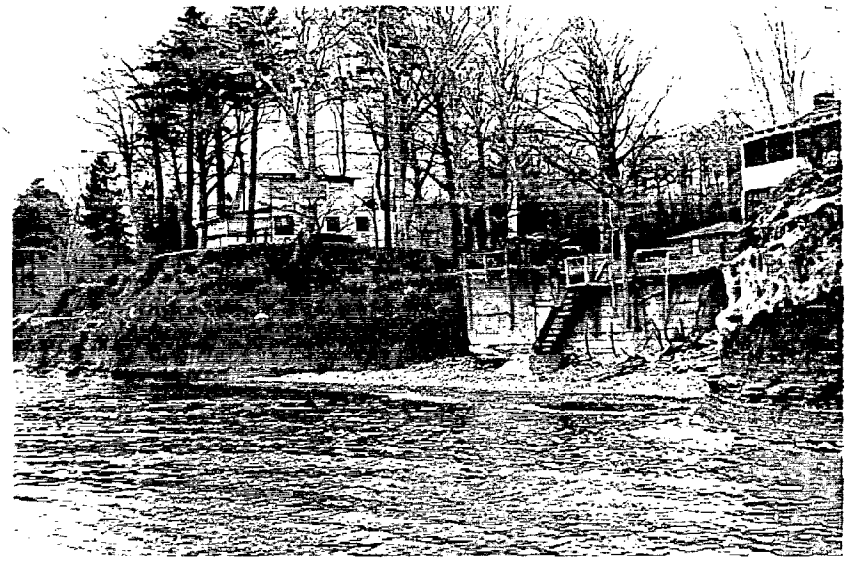
Above: Six Mile Creek, Harborcreek Township; showing formation of bay mouth bar

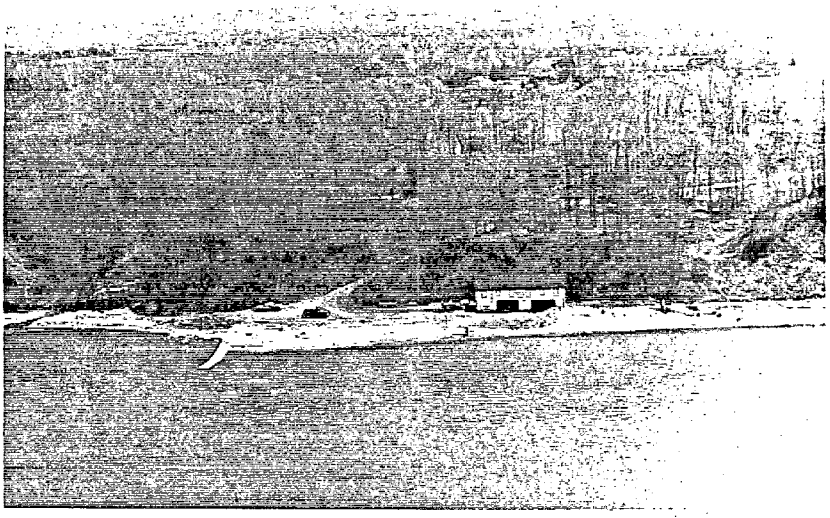


Above: Cowell's Beach cottages, east of Six Mile Creek, Harborcreek Township; showing scalloped bluff; also showing erosion of bluff crest due to wave uprush

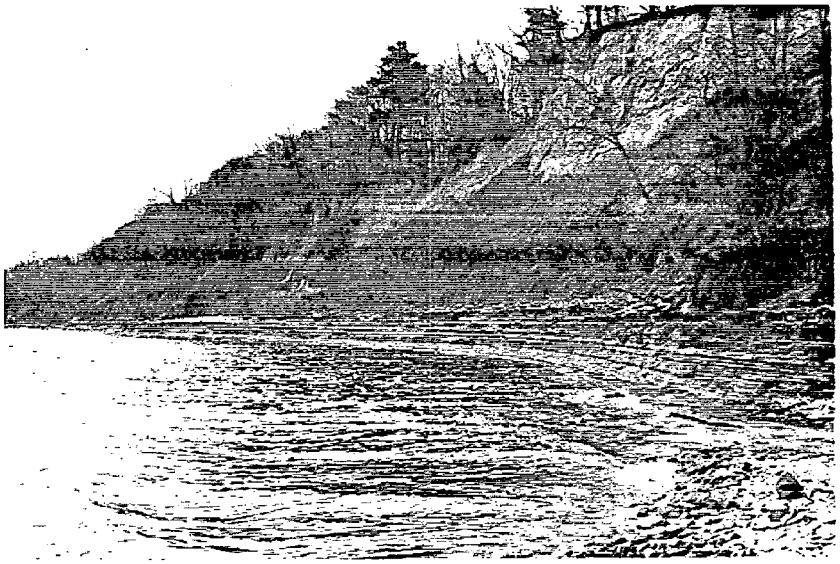


Above and below: Kraus Drive, Harborcreek Township

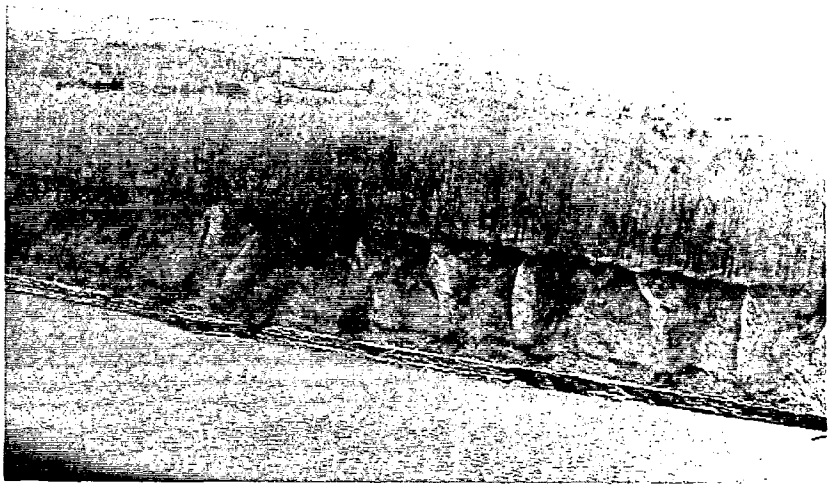




Above: Shades Beach County Park and Mouth of Eight Mile Creek, Harborcreek Township



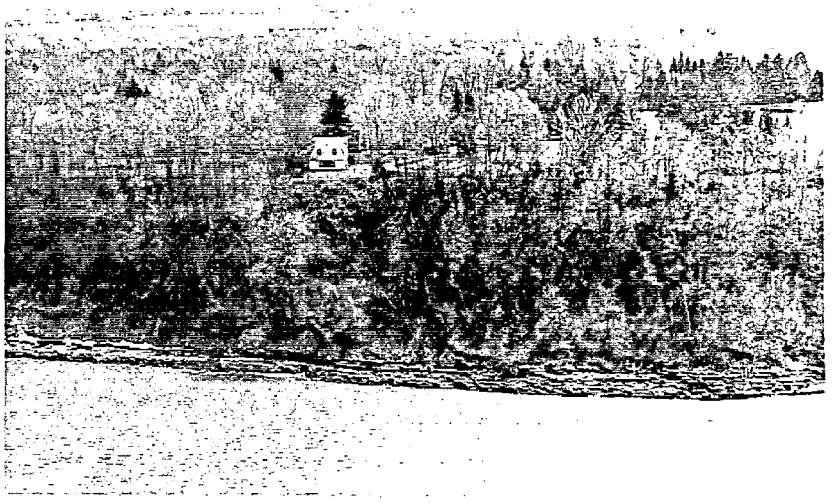
Above: View looking east of Shades Beach County Park, Harborcreek Township



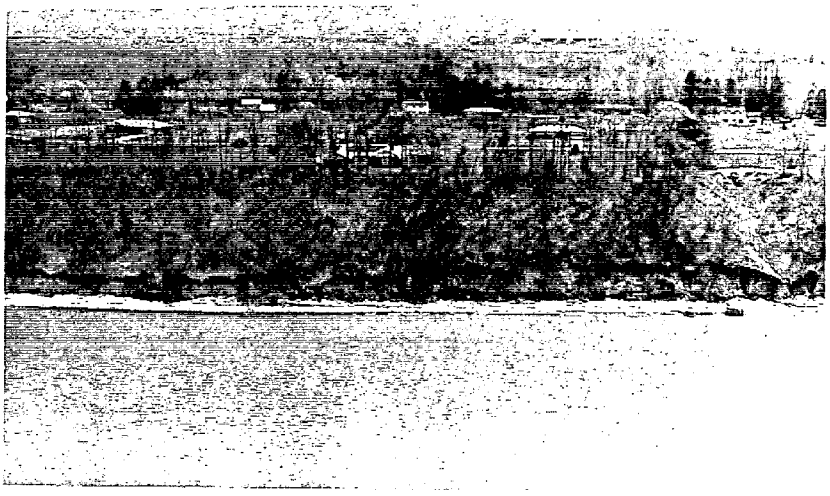
Above: East of Eight Mile Creek, Harborcreek Township

Above: Between Eight Mile Creek and Twelve Mile Creek, Harborcreek Township

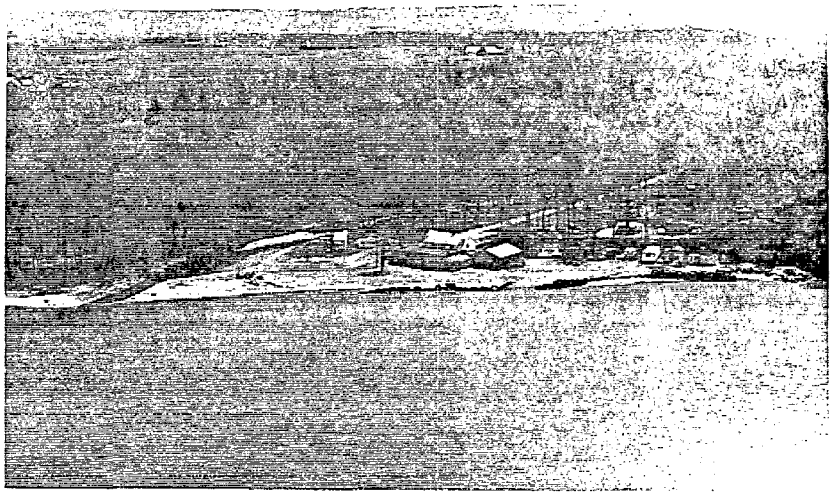
LOCATION:	Eight Mile Creek to Twelve Mile Creek
TOWNSHIP:	Harborcreek
PLACE NAME IDENTIFICATION:	Lake Shore Terrace, Carey Farms, Driftwood Drive, Windsor Beach Court, Shorewood Inn
LONGSHORE DISTANCE:	2.8 miles
BLUFF HEIGHT:	Rises to uniform 90-100 ft.
STRUCTURES SUBJECT TO DAMAGE:	55 homes, 8 cottages, and 1 tavern
CONTROL STRUCTURES:	One seawall at Shorewood
SHORE ZONE DESCRIPTION:	Bedrock begins at 4-6 ft., then disappears and then reappears, going to 15 ft. high. The bluff is near vertical with rapid recession just east of Eight Mile Creek. Then the bluff slope decreases to 60-70°. There is essentially no beach in this section. There is both toe erosion and crest slumping at sporadic points. The section is primarily a permanent residential area on the top of the bluff. The only beach development is at Shorewood, where several cottages and the Shorewood Inn have been damaged by storm-driven waves and flooding. A recently built seawall of concrete filled steel drums has offered some protection. However this control system is easily overtopped by storm waves and has suffered some vertical and horizontal displacement. The cottages on both banks of Twelve Mile Creek also are subject to flooding due to the damming of the creek by high lake water and the formation of a bay mouth bar.



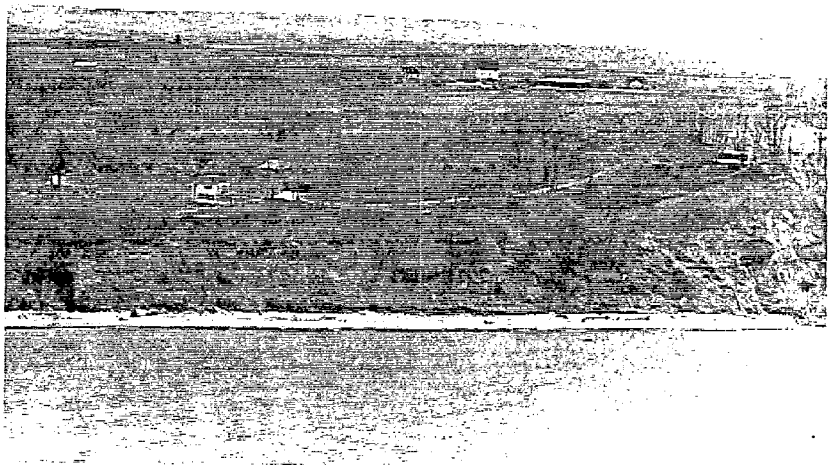
Above: Between Eight Mile Creek and Twelve Mile Creek, Harborcreek Township



Above: Lake Shore Terrace, Harborcreek Township; showing serious toe erosion and loss of beach access

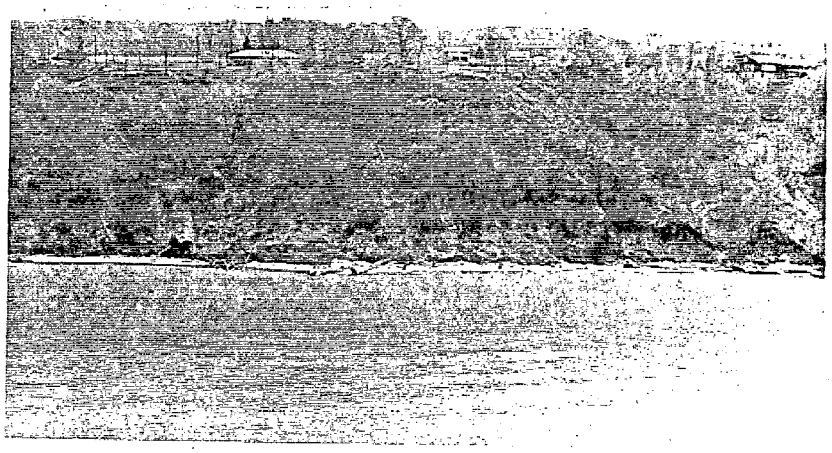


Above: Shorewood Inn, Twelve Mile Creek, Harborcreek Township



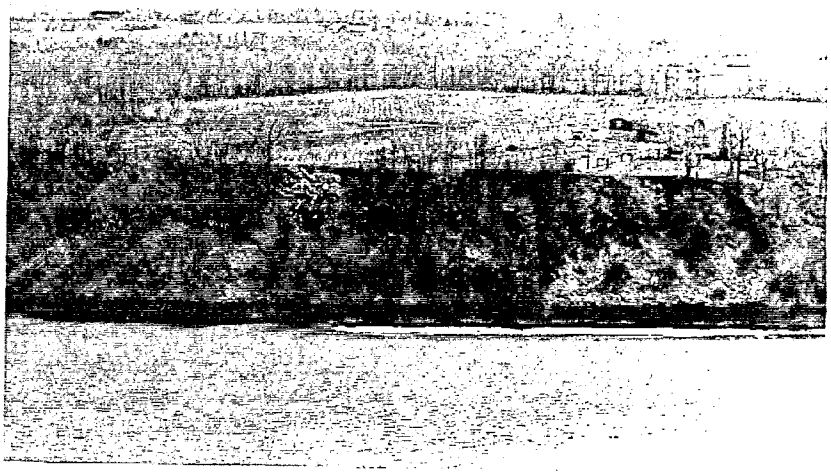
Above: Near Brickyard Road, North East Township; showing vertical bluff and structures in danger

LOCATION:	Twelve Mile Creek to Sixteen Mile Creek
TOWNSHIP:	North East
PLACE NAME IDENTIFICATION:	Brickyard Road, Cemetery Road, Sand Hill Farm, Freeport Lane
LONGSHORE DISTANCE:	5.0 miles
BLUFF HEIGHT:	100-110 ft. rising to 170 ft. west of Brickyard Road, decreasing to an ancient stream mouth and another low terrace area before Sixteen Mile Creek
STRUCTURES SUBJECT TO DAMAGE:	33, including 4 critical
CONTROL STRUCTURES:	None
SHORE ZONE DESCRIPTION:	This section contains the highest bluffs in the county. The bluffs are mostly covered with vegetation and are sloped at 60-70°. Bluff crest usage is primarily agricultural-grape vineyards and fruit trees - with some permanent and summer residential usage. In a few places the bluff vegetation is disrupted either by toe erosion or surface drainage. The bluff crest is severely dissected and scalloped due to interior drainage from the farmland. There are older slumps in various places. The bluff is generally stable, except for a few critical areas, including two homes in danger near Brickyard Road. Bedrock disappears and then reappears in this section, with thickness from 0-15 ft. There is an almost continuous beach strand of 10-20 ft. during low water. At Sixteen Mile Creek, there is a gravel and shingle public beach formed by the stream mouth.

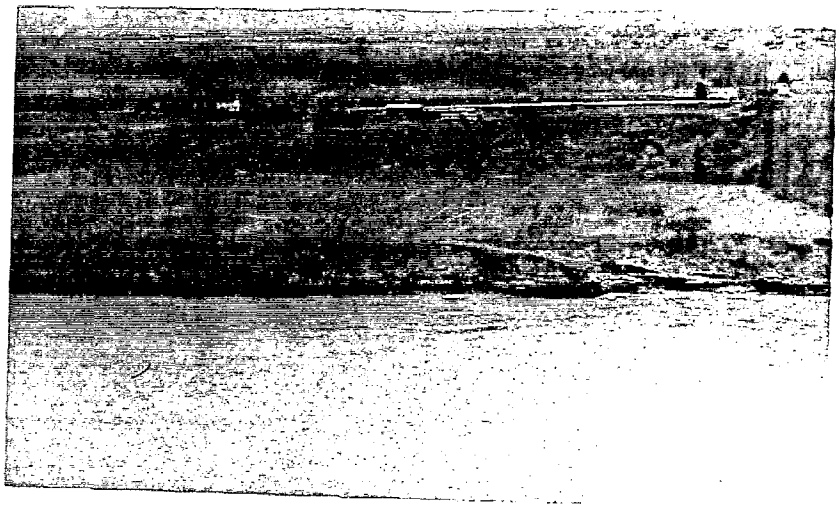


Above: High bluff section between Twelve Mile Creek and Sixteen Mile Creek, North East Township

Above: East of Brickyard Road, North East Township; showing cottages on low delta area which dissects high bluff section



Above and below: Between Twelve Mile Creek and Sixteen Mile Creek, North East Township; showing agricultural use to bluff crest



SECTION 5
RECESSION RATE ANALYSIS
(By Section with Correlations to Site Location)

The following narrative represents a synthesis of recession rate data (Appendix C) with Coastal Zone features, both natural and manmade. The rates determined by the direct measurement techniques are explained as to variation in time and space.

DESCRIPTION OF RECESSION RATE MEASUREMENT TECHNIQUE

Photogrammetry

Aerial photographs of the years 1938-39, 1:20,000 scale (ASCS); 1959, 1:20,000 scale (DOA), and 1974-75, 1:14,000 and 1:24,000 scale (Erie County Department of Public Works) were utilized. Stereo pairs were available for all three sets for stereoscopic comparisons of coastline changes and recession phenomena. (A mirror steroscope, with 4X binocular heads was used to assist in bluffline delineation.)

Scale comparisons were performed with the USGS 7-1/2 Minute Series of topographic maps as the principal control. The topographic maps are recent with photo-revisions through 1969. A computer program was written to bring each set of aerials into common denomination with the topographic series.

Procedure

A precision measuring device, the Microline Super Gage, was used to measure distances common to the topographic map and the three sets of aerials. The Super Gage measures under 40X in thousandths of an inch. A 10X scope, with crosshairs, allows precision alignment of points for comparative measurement. The data obtained is then computer coded for scale determination.

Recession measurements were taken from selected locations along the shoreline where conformity between the three series of aerials could be established. In most instances, the points were established where recession of greater than 0.6 foot per year was apparent since an active slope could be identified much easier than a non-active one. The points average approximately 0.4 mile apart and include all varieties of slope condition, land use on the crest, and beach conditions at the toe of the bluff.

Bluff recession was measured by selecting points common to the aerial imagery using clearly defined geographical locators, principally east-west trending highways as the control line and north-south trending roadways, private drives, clearly defined fence rows, and outstanding permanent features as the measurement line to the bluff's edge. These measurements were taken using the Super Gage and computer coded for analysis. (See Appendix C.) The location of these points are shown on maps contained in this section.

PROBLEMS ENCOUNTERED

There is some inherent difficulty in utilizing aerial photography for recession analysis. First, the photographs themselves are of the nominal

scales indicated but actually vary to some degree between photographs and within the photograph itself. We feel that by proper scale justification, a number of times in any photographic sequence, most of this problem has been eliminated.

Second, at the latitude of Erie County, Aerial photographs taken under the best of circumstances (mid-June in early afternoon with sun angle at its highest), the resultant photograph places the bluff face under shadow which makes it extremely difficult to determine the crest of the bluff where vegetation is a factor. The measuring points were carefully selected to avoid this difficulty as much as possible.

Third, the 1959 coverage was flown in August when vegetative cover is at its maximum. Where trees line the shore, the canopy obscures the bluff crest making it nearly impossible to delineate the actual bluff line properly. The 1938-39 coverage and the 1974-75 coverage were flown in early spring. Vegetation is of little consequence and the bluff line can be seen with maximum clarity under most conditions. The recession rates have been established for this report using the differences between the 1938-39 line and the 1974-75 line so that a long term average under the most ideal conditions can be established.

Fourth, tilt in the aircraft as the pictures are shot can create distortion in the photograph making measurement to a nominal scale difficult. Government contract photographs have a guarantee of less than 3° of tilt. Therefore, the 1938-39 imagery and the 1959 imagery are within the standards. It is not known with what degree of precision the photographs taken under contract with the Erie County Department of Pulbic Works were done. By scale conversion a number of times on any photograph, the effect of tilt, if any, has been minimized.

Fifth, picture clarity is more of a problem on the older imagery. It is well known that the state of the art in 1939 did not provide the image clarity available today. By careful selection of measuring points, most of the problem of bluff delineation due to clarity difficulty was eliminated.

Advantages in Availability of Materials

For the type of data collection involved in recession analysis, the Commonwealth of Pennsylvania is fortunate to have available to a complete, updated series of 7-1/2 minute topographic maps facilitating comparisons with current aerial imagery.

We were also fortunate to have excellent aerial coverage of the shoreline, making historical comparisons possible. Coverage, beginning in 1938 and every ten years thereafter (1950, 1958, 1969 and 1974-75), was available to us. By coincidence, the Erie County Department of Public Works had commissioned a complete photo reconnaissance of Erie County for purposes of Planning for sewer and water mains throughout the county. Therefore, we have a great deal of analytical capability for historic as well as current coverage. Because of the accelerated erosion and recession that has taken place during the period 1972 to the present time, the existence of current imagery is invaluable.

The degree of land use development in Erie County has been a distinct advantage in this project for recession rate analysis. There exists, in the

Coastal Zone, excellent control lines in the form of primary and secondary roadways. The existence of these roads makes it possible to set definite control lines easily referenced in 1938 as well as 1975. The absence of such controls would hamper analysis and the results would suffer appreciably.

Most of the shore zone is in some type of land use with the result being the elimination of forest cover as a disadvantage in analysis. Residential use, and agricultural use, in the bluff area, while presenting some hazard to the owner, has, nevertheless, made it possible to delineate bluff lines in most areas with a minimum of difficulty.

RECESSION RATE ANALYSIS

The following narrative is a sectional analysis of recession rates and the factors affecting the relative rates produced, as well as a general description of the bluff area involved. The maps accompanying the narrative illustrate the area covered by each section, the location of the recession rate measurement points, as well as other pertinent information.

For those areas where change is evident on a mappable scale, diagrams of those areas are presented illustrating bluff and shore recession over time and include a measure of the degree of threat such change has on the coastal zone.

Photographic documentation included in this section of the report graphically portrays the seriousness of physical change in relation to human use.

SECTION 1 Ohio State Line to Elmwood Road

The entire section can be characterized by rapid recession over the period of record. High water levels have had devastating effects at the base of the slope producing a near vertical bluff.

Points 01-1 and 01-2 average 22.2 inches annually. There is every indication that recession has been greatly accelerated in the past five years. At a particularly critical point in this section, the investigators witnessed four feet of recession from February to April, 1975. Fallen large blocks of material and slumping are readily apparent. An entire row of trees has disappeared since 1940.

Point 01-3: Recession reduced somewhat due to protection offered by slight foreland to west. Accumulation of material at the base of the bluff offers a measure of protection. Erosion at crest remains accelerated, however, due to ground water seepage producing a less than vertical bluff with slumping apparent.

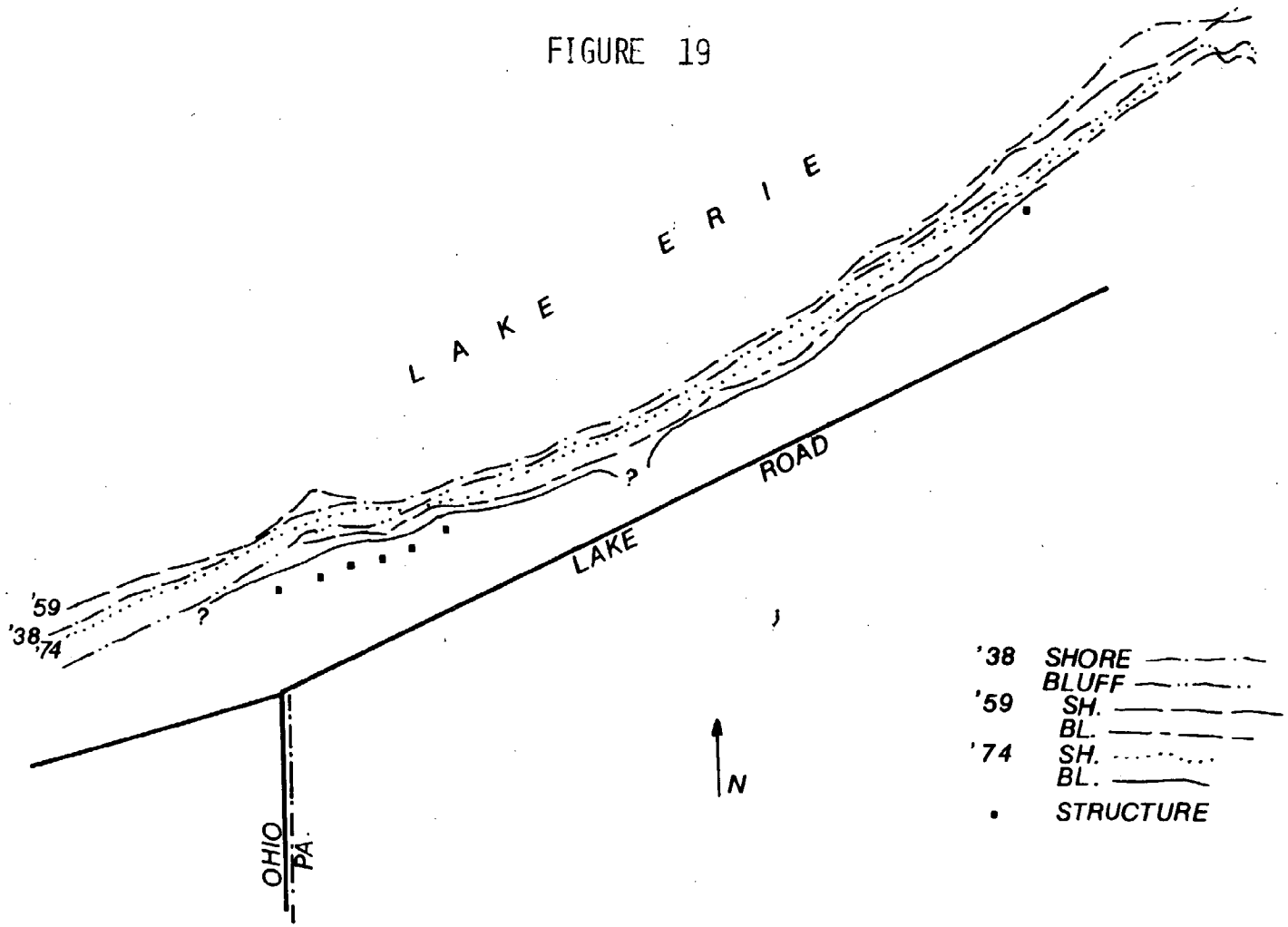
Point 01-5: A foreland-cove combination here is producing an "end of groin field effect," deepening the cove and threatening the roadway. Recession rates of 23 inches annually have been measured placing the bluff less than 100 feet from the road by the year 2000.

Points 01-6 - 01-8: Represent a headland-cove combination. The headland is being planed off and the cove deepening; recession is 18 inches annually in this area. Since 1939, the Lake Road has been relocated in this area, and by 1974 the former roadbed has been eroded. The recession rate would indicate that the relocated road will be within 100 feet of bluff by the year 2000 and again imperiled.

SECTION 2 Raccoon Creek to Camp Lambec

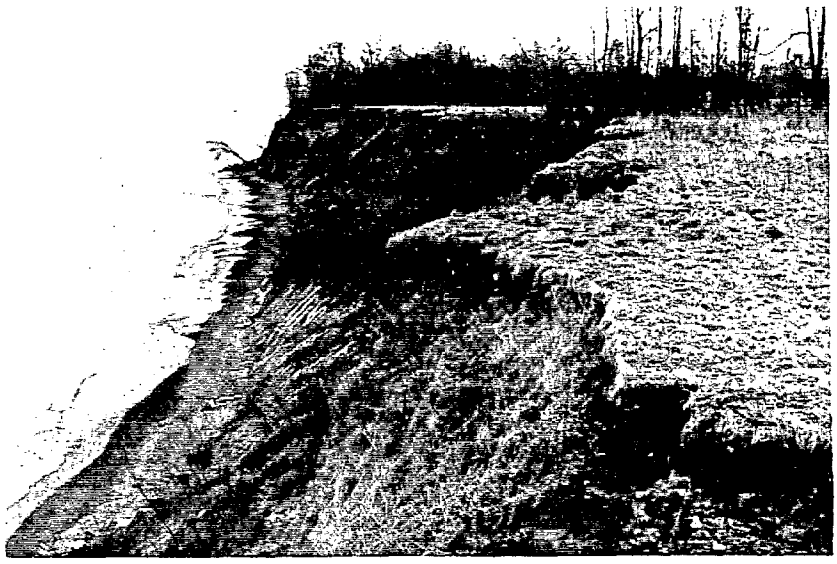
Point 02-1: Raccoon Creek County Park--average recession in that area is 36.4 inches. The recession rate was measured for the mouth of Raccoon

FIGURE 19



U.S. STEEL COTTAGES

Above and below: Slopes of various slope produced in relation to recession activity in Springfield Township



Creek; no bluff is present. There is extensive damage in the form of sand removal, tree loss, threat to picnic shelters, and flooding from the stream, as well as from high water and storms.

The groin to the west of the park is severely damaged, thus having little effect. The groin is improperly placed for the production of sand accumulation at the park.

Average recession of Points 02-3 and 02-4 is 20.75 inches, and erosion and recession are quite apparent. The slopes are steep and devoid of vegetation. Ground water seepage is an obvious factor of slope failure. The land was in agricultural use until the late fifties, and now is undergoing plant succession, but the bluff crest is essentially unprotected. In one section, grass is being mowed to the edge of the bluff.

Recession has been extremely active during the past year.

Point 02-5: Two groins constructed after 1959 have allowed for the development of beaches, having an expected effect on recession, which has been somewhat slowed in the current period after construction. The average, however, is still 22.9 inches.

Point 02-6: Ellis Road - Eagley Road - There is high density cottage development in this section; bluff recession is not a constant phenomenon. Groins constructed to the west after 1960 may be adversely affecting stability in this section. Small groins and seawalls have protected this section during low water. The recession average for the period is 5.9 inches.

Point 02-7: The bluff here rises vertically from the flood plain of the stream. While devoid of vegetation, there does not appear to be rapid recession. Interior drainage is absent and the base is protected by a groin and seawall combination at a township-maintained beach. The recession is 4.5 inches per year.

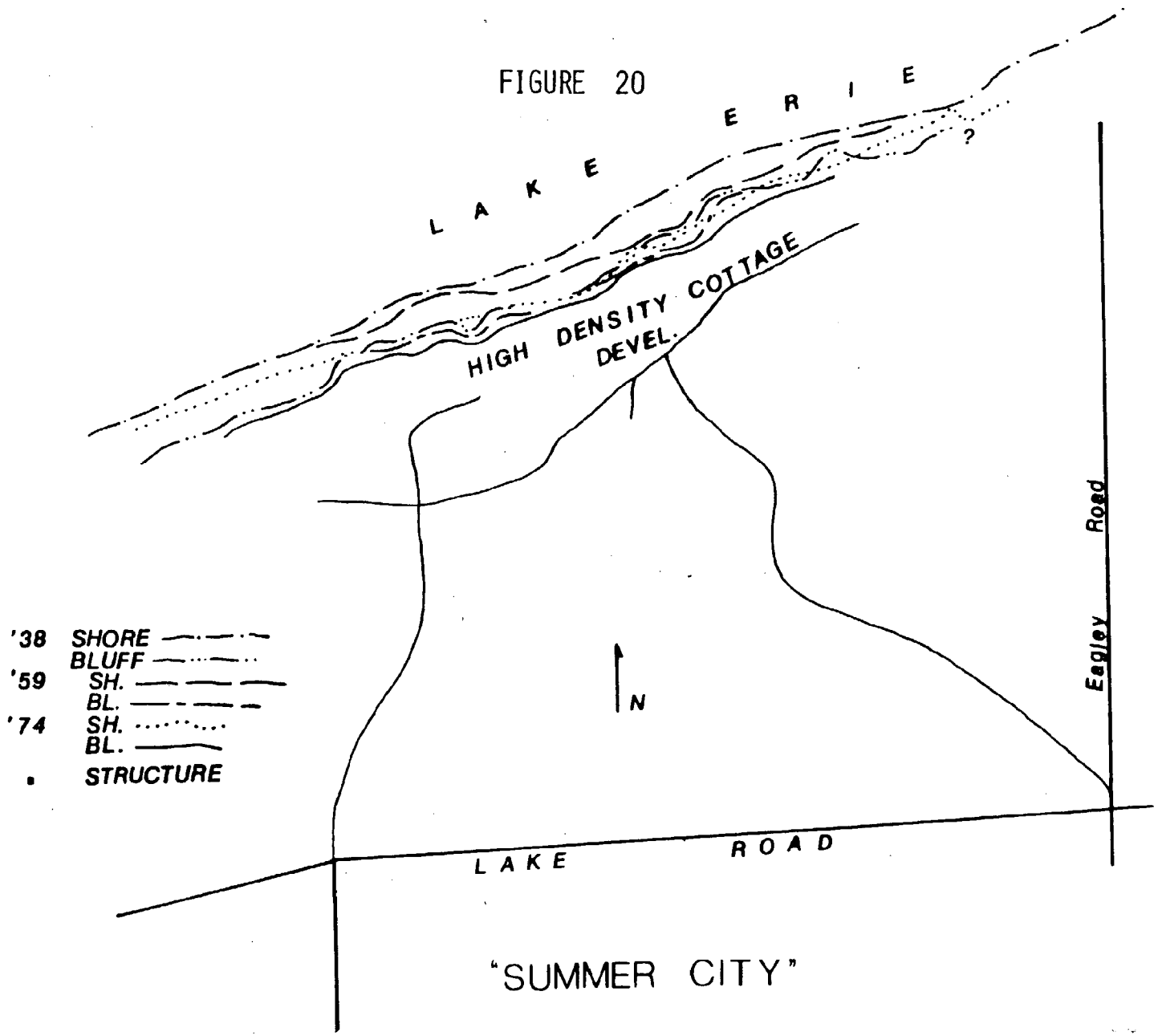
Point 02-9: Recession here is 7.4 inches annually. A large private camp has placed several groins to protect the bluff and maintain beaches for recreation. The groins were constructed after 1960 and have had measurable success.

SECTION 3 Crooked Creek Vicinity

Point 03-1: There is a 10-15 ft. vertical bluff on either side of a boat access which is deranged and the evidence indicates a significant loss to both the beach and the bluff during the past three years. The investigators witnessed six feet of recession from February to April, 1975. This point is unprotected by any device and storm damage is severe to existing residential structures.

Point 03-2: A foreland-cove combination, the measurement point is in relation to the cove; the bluff is not clearly defined. The recession measured is beach erosion over the period (10.1 inches is the annual average). During lower lake levels, it is expected that this area will accumulate sand, offering a measure of protection to this area.

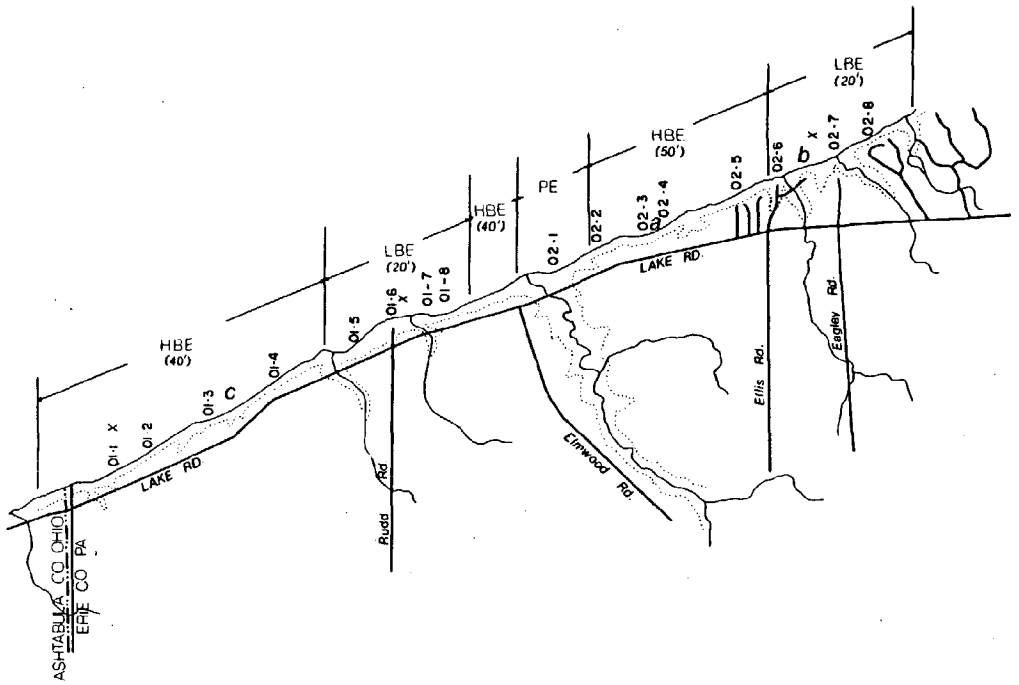
FIGURE 20

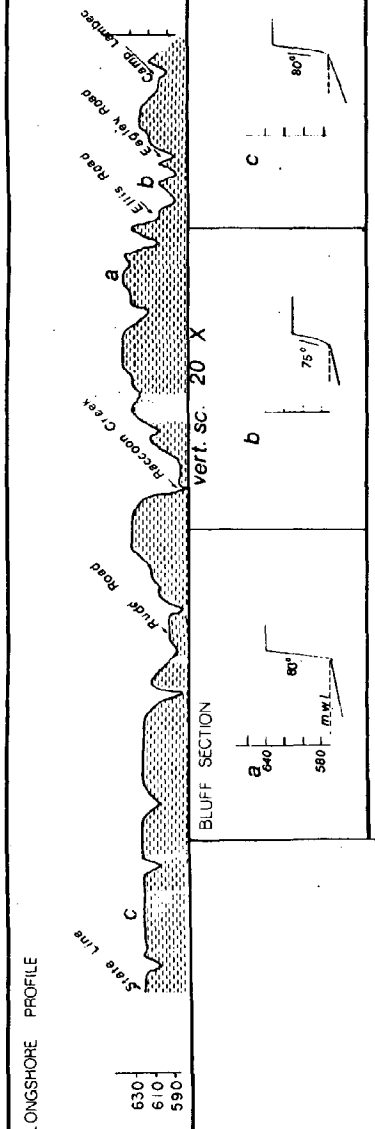


"SUMMER CITY"

SHORELINE CHARACTERISTICS

Pa. State Line to Camp Lambec





1. BLUFFS OF LOW TO MEDIUM HEIGHT, SEVERELY DISSECTED BY TRIBUTARIES
2. COTTAGE AND CAMP AREA
3. THIRTEEN GROINS; THREE BREAKWALLS
4. CRITICAL AREAS: STATE LINE TO RUDD ROAD — ELLIS ROAD
   RUDD ROAD TO ELMWOOD ROAD — EAGLEY ROAD
   RACCOON CREEK COUNTY PARK

Legend

01-1	Photogrammetric Control		
X	Survey Control	LBE	Erodible Low Bluff
	Approx. Bluff Line	PE	Erodible Plain
a	Section Location	(40')	Minimum Ht.
*HBE	Erodible High Bluff		

* See Appen. A

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Konecnic ESC

Points 03-3/03-4: Both these points are located at Camp Fitch. The bluff is divided into two sections by conditions. Point 03-3 has been stabilized somewhat by the construction of three major groins. Vegetation on the slope has taken hold and recession has been minimized. However, Point 03-4 has experienced massive recession recently. Measurements of slump blocks displaced during the winter season of 1974-75 indicate as much as 25 feet of recession has taken place in four months. While the phenomenon would require further study, the indication is that the groins to the west have produced this accelerated slope failure.

Between Points 03-4 and 04-1, the bluff is relatively stable. The entire section is protected back from the bluff by second growth timber and on the bluff face by mixed vegetation.

One section, Eagles Nest on Camp Sequoyah property, is point recession produced in association with groins at Camp Fitch to the west and ground water seepage. This land was farmed prior to 1938 and allowed to regenerate since its purchase as a camp.

SECTION 4 Camp Sequoyah Vicinity

Point 04-1: This is an exposed bluff section, but recession is moderate due to the placement of protection devices on the beach for sand accumulation providing the camp with beach facilities. One groin was established 20 years ago and one was established recently. McBrier Lodge, belonging to the camp, is within 53 feet of the crest and is in moderate danger.

Point 04-2: Validity of this point is in question. Bluff delineation is extremely difficult due to dense vegetative cover. Taken in context with other areas, however, a recession rate of 9.6 inches annually seems reasonable.

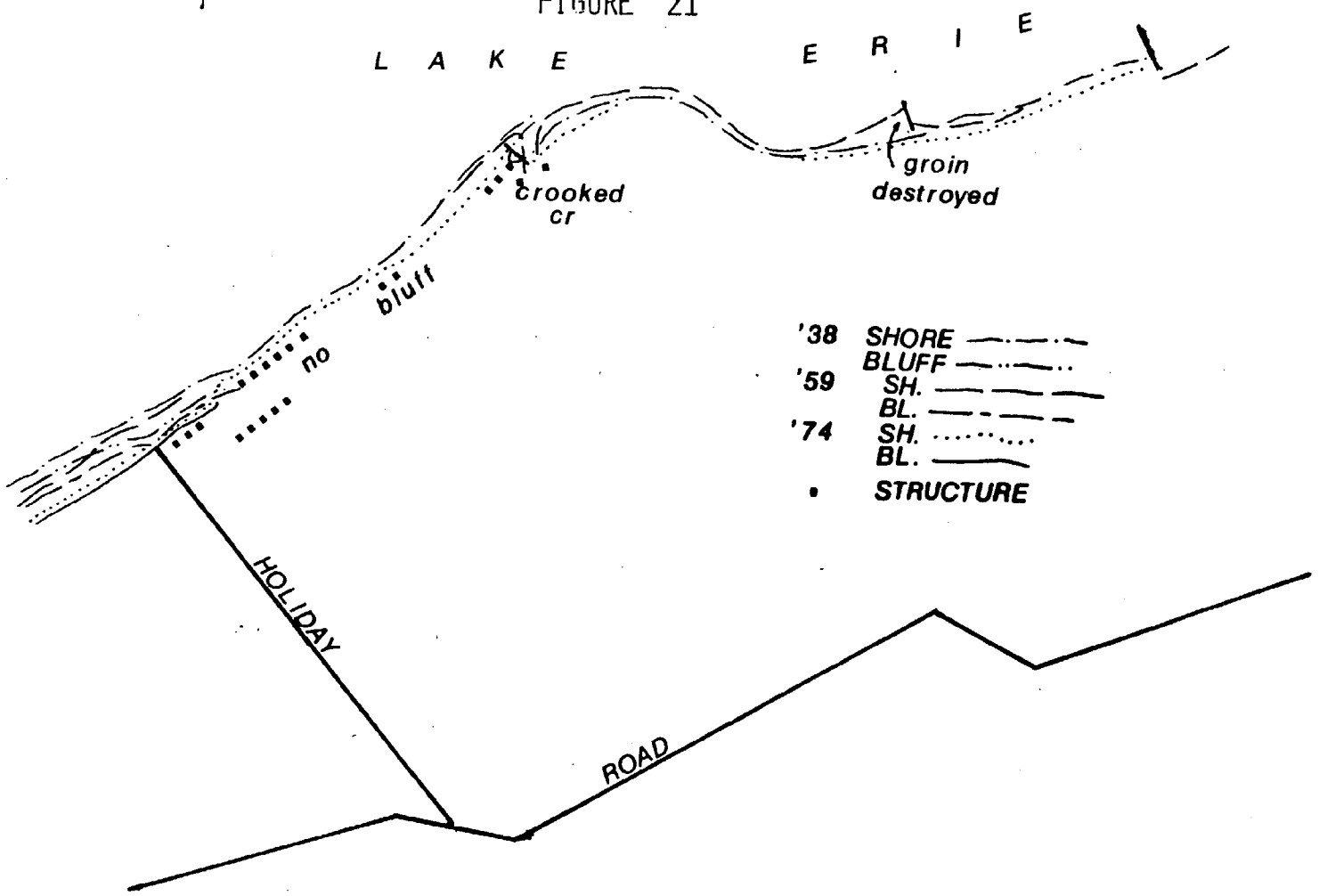
SECTION 5 Camp Sequoyah to East of Elk Creek, Girard Township

Points 05-1 and 05-2: A great deal of change is evident over these points due mainly to agricultural runoff producing an enlargement of stream drainage on the bluff slope. Headward erosion and valley widening by the streams would appear to be the prevalent force in Point 05-1, while normal processes are responsible for more gradual change. The recession measured in Point 05-2 seems exaggerated. Further ground evaluation is indicated. A private engineering firm under contract with the Pennsylvania Electric Company has reported no significant erosion problems in this area. The truth probably lies somewhere between these extremes.

SECTION 6 Elk Creek to Lake Erie Community Park, Girard Township

Point 06-1: The 52.7 inches of annual recession computed is shoreline recession at Elk Creek Bay access area. Changes in the delta deposits have been dependent on water levels, storm activity, and ice cover, all of which have been severe in the negative over the past three years. The sediments produced by Elk Creek have not kept pace with the removal of delta deposits by the longshore transport systems. A groin to the west of Elk Creek has been severely

FIGURE 21



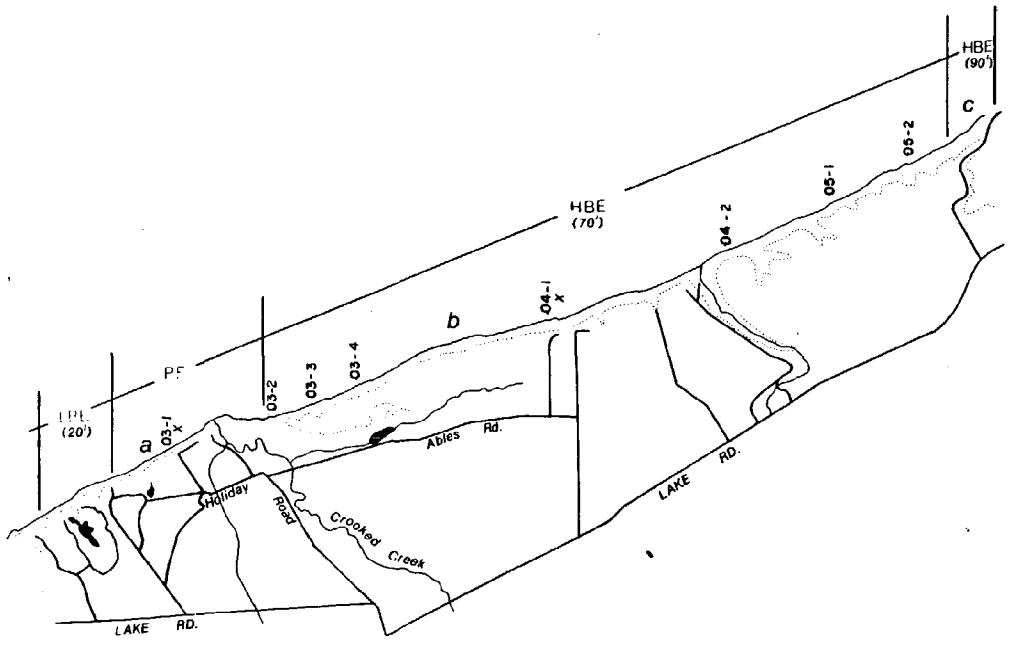
HOLIDAY SHORES

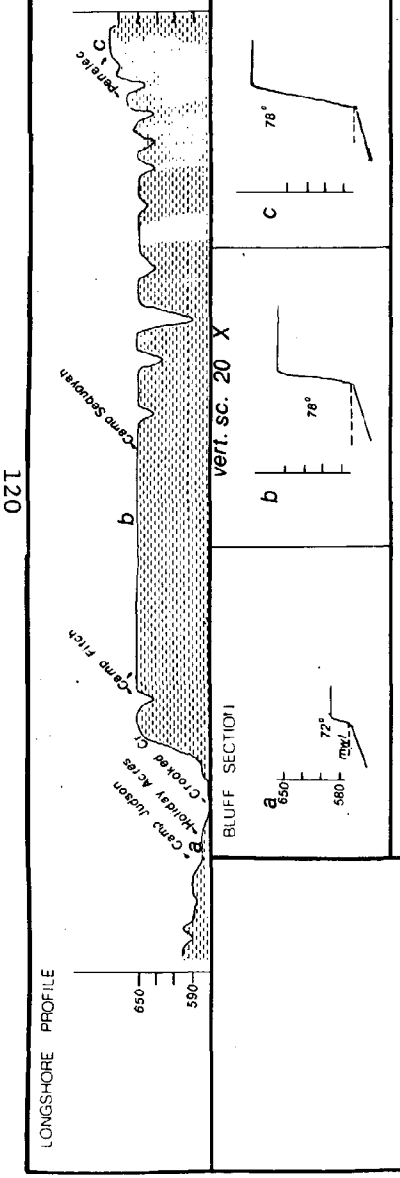
Above: Slumping with associated vegetative disruption, Girard Township

Below: Vertical bluffs with block falls occurring, Springfield Township

SHORELINE CHARACTERISTICS

Camp Lambec to Elk Cr.





NOTES

1. GENERALLY A HIGH BLUFF AREA WITH LOW BLUFF AND STREAM MOUTH AT WEST END OF SECTION
2. CAMP AND COTTAGE AREA PLUS UNDEVELOPED PENELEC SITE
3. TEN GROINS; ONE BREAKWALL
4. CRITICAL AREAS: DAN'S BEACH, HOLLIDAY ROAD, CAMP JUDSON, CROOKED CREEK

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- * See Appen. A
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht.

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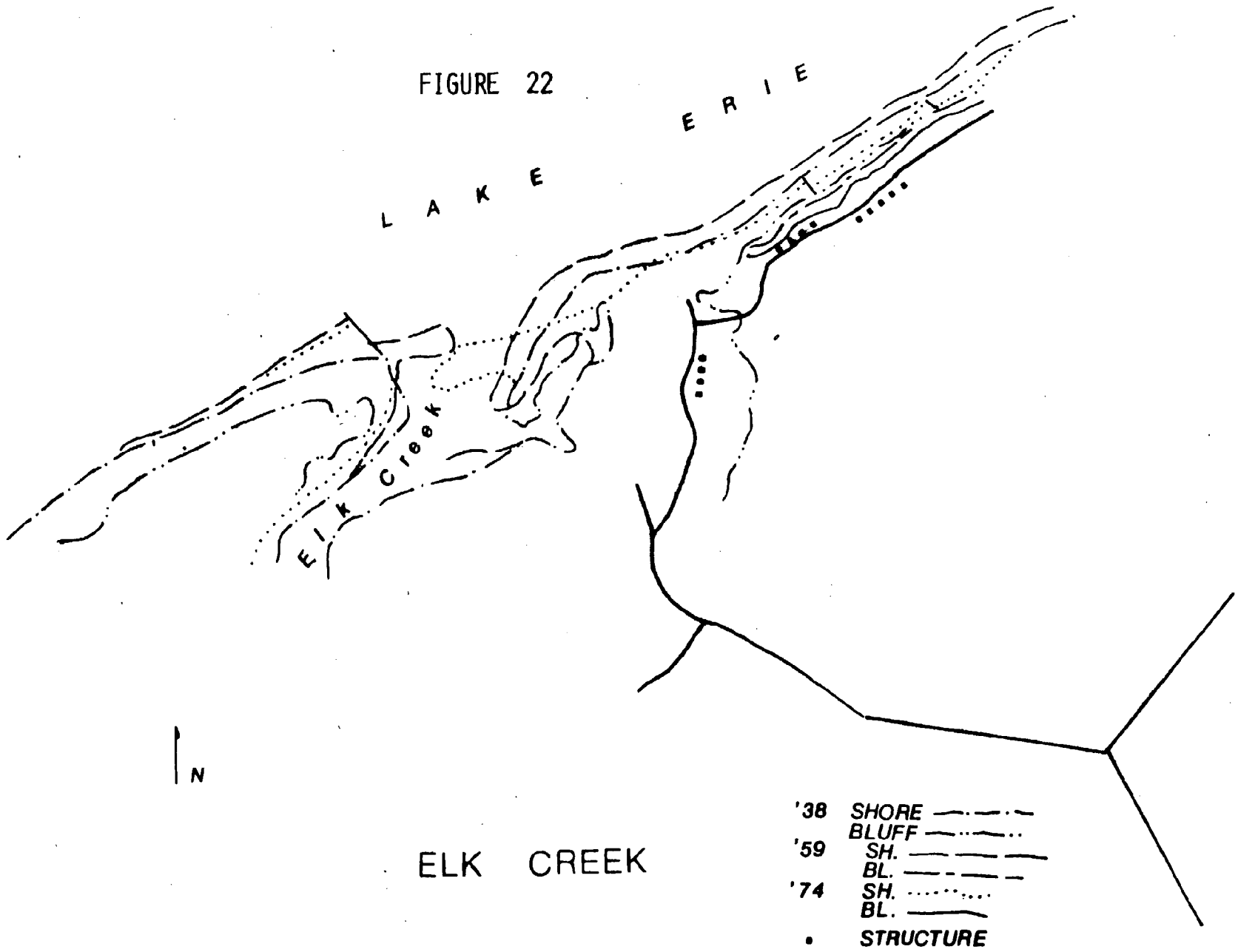
FIGURE 22



ELK CREEK

damaged. There is some question of the relative benefits of the structure in any case. The Fish Commission has proposed a structured access for this area. It is strongly recommended that a full study be made of conditions here before this is done, to prevent a repeat of the problems occurring at Walnut Creek to the east.

Points 06-2 to 06-5: These points exhibit relatively stable slope conditions with two startling exceptions noted below. Recession, as measured, is average for the shoreline; however, accelerated recession west of Point 06-2 is evident. A series of groins at this point has a limited effect on bluff recession. Recession is related to an unvegetated crest, septic tank outfall, and road drainage in addition to normal ground water seepage and high water levels.

Lake Erie Community Park at Point 06-4 has perhaps the most dramatic evidences of bluff recession phenomena on the entire coast. During the past year and a half, Park Commissioners have been recording a massive amount of slope failure producing slump blocks of extraordinary dimension. Slope failure is quite apparent in all stages of occurrence.

Investigators feel that the greatest contributory cause is abnormally high amounts of lacustrine deposits in the area and extremely high ground water conditions over the past three years. The deep sand deposits become quite unstable with the addition of large amounts of water.

Slump blocks of the following description have been examined:

(1) A deranged block with landslide characteristics with complete derangement of materials and vegetation.

(2) A block approximately 30 ft. by 150 ft. with a vertical displacement of 60 ft. from top of bluff. Trees in second growth are deranged, though some still upright.

(3) A block with vertical displacement of 8 ft. measuring 41 ft. wide by 165 ft. long, with definite continued movement evident.

(4) A crack and displacement of a few inches indicates continuation of activity to the east of (3) above. Anticipated dimensional proportions would indicate a slump of material 30 ft. wide by 250 ft. long.

There is strong indication that this process has been repeated through time on various sections of coastline. One notable location in the Millcreek Township area (Montpelier Avenue to Kelso Beach) has indications that this type of activity has taken place, probably as much as 60 years ago or more.

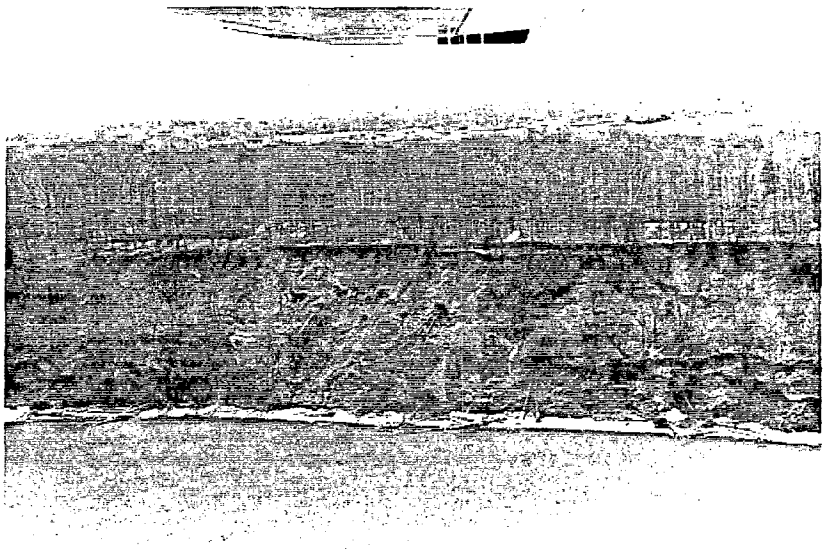
SECTION 7 Lake Erie Community Park to Camp Eriez (formerly Caledon), Girard Township

There is extreme variability in recession rates along this section due

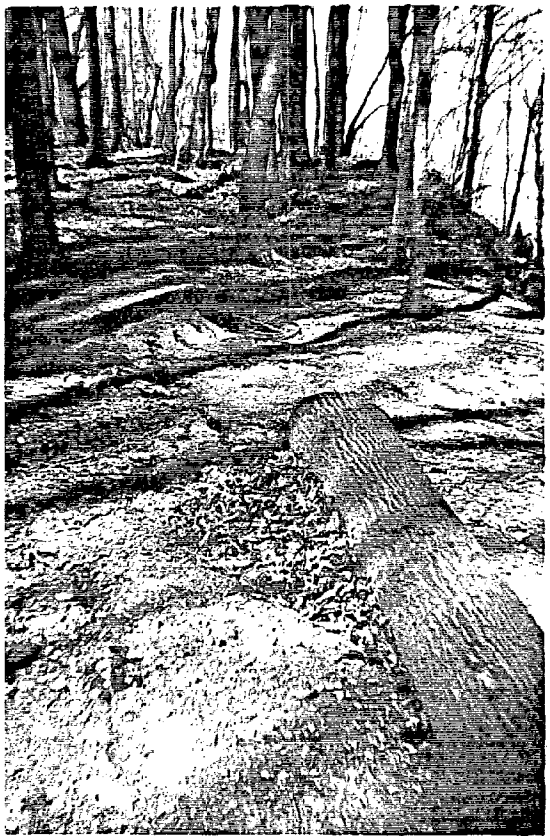
This set of four photographs documents the degree of activity at Lake Erie Community Park. Three distinct slides are evident in (1), (2), and (4). (3) shows aerial view of area.

1

2



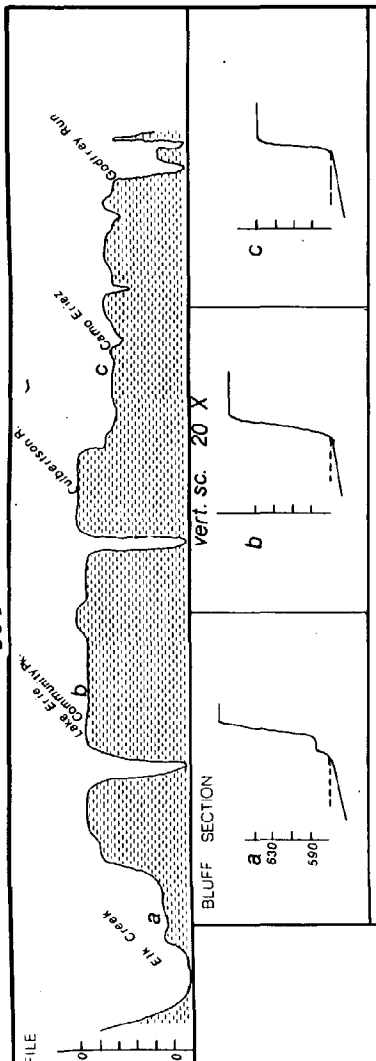
3

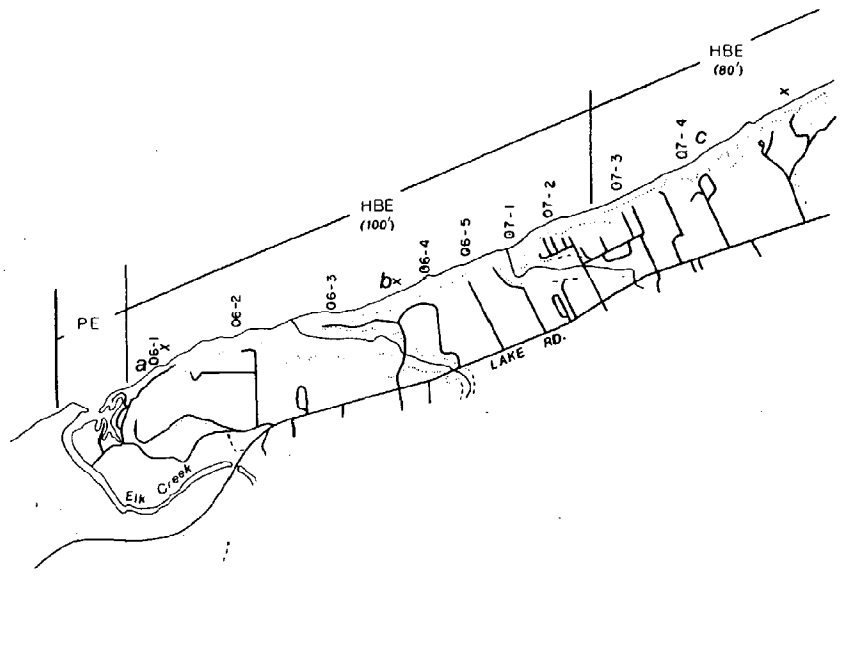


4

SHORELINE CHARACTERISTICS

Elk Creek to Godfrey R.





NOTES

1. GENERALLY HIGH BLUFFS WITH THREE STREAM CUTS; SEVERAL AREAS OF SEVERE SLUMPING
2. COTTAGE, PARK, AND CAMP AREA
3. EIGHT GROINS; ONE BREAKWALL
4. CRITICAL AREAS: ELK CREEK MOUTH; ELK CREEK - BLUFF COTTAGES; LAKE ERIE COMMUNITY PARK; CULBERTSON ROAD

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht
- * See Appen. A

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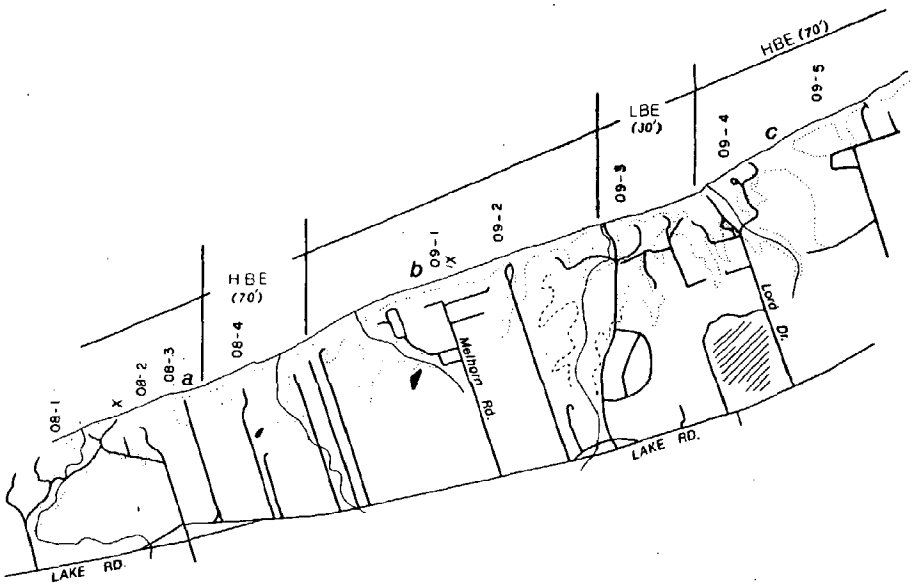
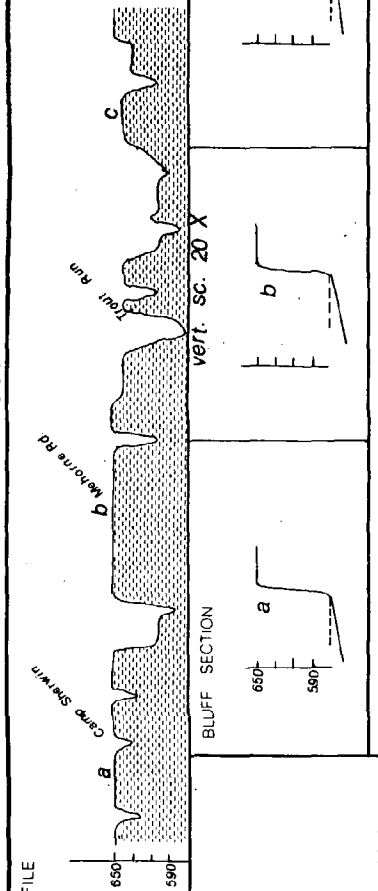
SHORELINE CHARACTERISTICS

Godfrey Run to Eaton Rd.





NOTES

1. HIGH BLUFF AREA SEVERELY DISSECTED BY STREAMS AND TRIBUTARIES
2. MIXED RESIDENTIAL, COTTAGE, AND CAMP AREA
3. SIXTEEN GROINS; TWO BREAKWALLS
4. CRITICAL AREAS: GODFREY RUN/FAIRPLAIN ROAD

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- * See Appen. A
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht.

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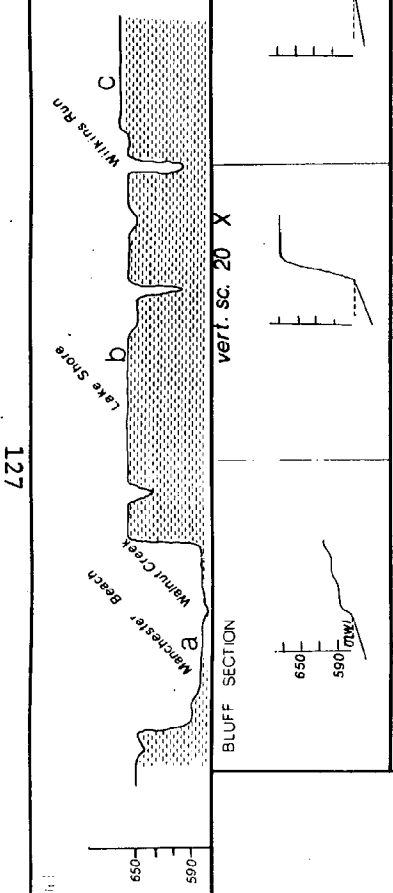
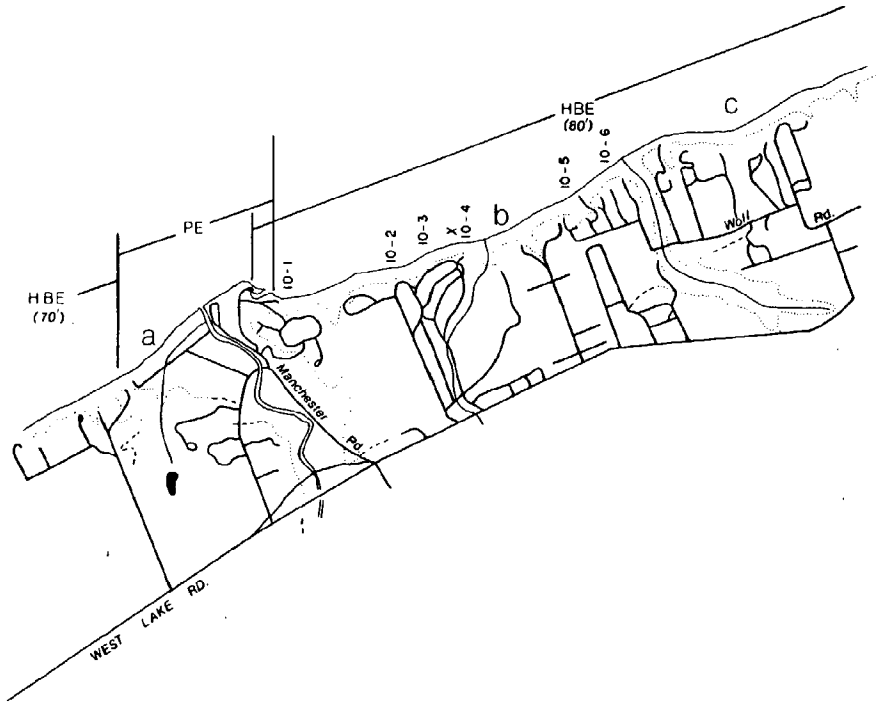
SHORELINE CHARACTERISTICS

Eaton Road to Wolf Rd.





NOTES

1. High bluff area with plain at Walnut Creek mouth
2. High value residential area plus Fish Commission Access Area
3. Fifteen groins and two breakwalls
4. Critical Areas: Walnut Creek Fish Commission Access Area

LEGEND

01-1	Photogrammetric Control			
X	Survey Control	LBE	Erodible	Low Bluff
	Approx. Bluff Line	PE	Erodible	Plain
a	Section Location	(40')	Minimum	Ht.
*HBE	Erodible High Bluff			

* See Appen. A

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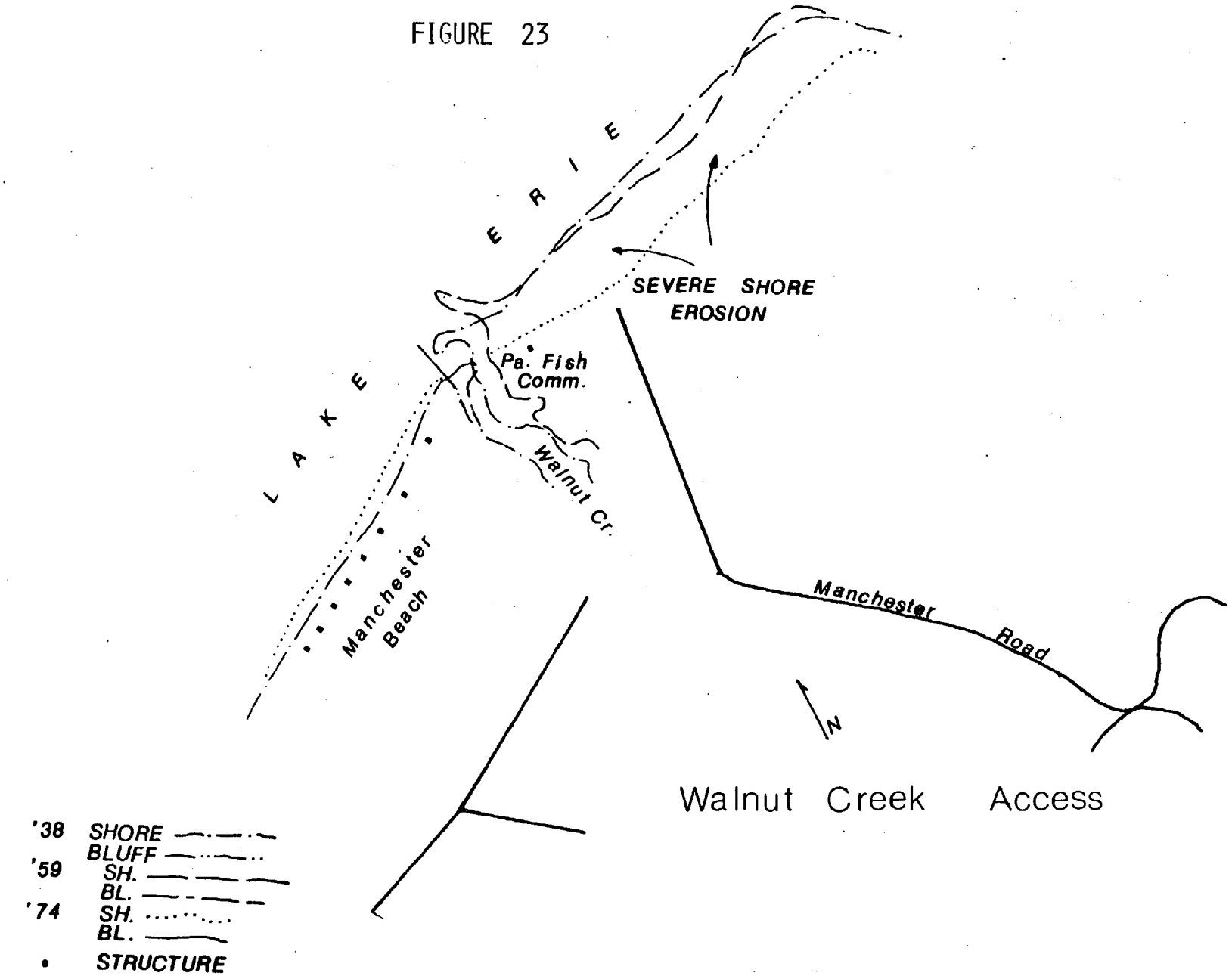
FIGURE 23



Walnut Creek Access

to differences in slope, shoreline, and use.

Point 07-1: Is in a cove with some sand accumulation offering limited protection. There is, however, evidence of rapid recession at the toe of the bluff by wave action which is overriding the beach berm. There is an increasingly common phenomenon, a second bluff producing a step effect, representing a differential wasting of materials. This secondary bluff is evidence of rapid erosion rates at base and somewhat stable condition on the bluff above, produced either by material resistance of a heavy blanket of vegetation. Just to the east, for example, is an elevated stream mouth, an indication that recession is outpacing stream downcut.

Point 07-2: The recession rate was based on an error in photogrammetric interpretation due to the relocation of a private access road and must therefore be discounted.

Point 07-4: Reduced recession at this point is due to slope stability. The base is protected by two groins with an accumulation of beach deposits.

SECTION 8 Camp Eriez to Camp Sherwin, Girard Township

There are eight groins protecting private property in this section. The result is some stabilization at those points. However, the placement is not spaced to provide protection for all. As a result, there are areas experiencing accelerated erosion due to natural phenomena in combination with effects produced by groin placement.

Since the groins are relatively new, the expected effect will not be measurable for some time. Most slopes are relatively stable and severe problems are the exception. New construction and change in land cover at Point 08-3 will undoubtedly create difficulties for the owner in the future.

Points 08-1, 08-2, and 08-4 are protected by vegetated slope in combination with groins and are not considered especially threatened.

SECTION 9 Melhorne Road to Eaton Road, Fairview Township

The distinctive feature of this section is the Trout Run access area. West of Trout Run, the bluff is stable with only minor, highly localized, problems; and east of the area, the same conditions exist. The slopes are protected by vegetation and little activity is apparent.

In the vicinity of Point 09-4, there are two properties where vegetation has been reduced to grasses. Both areas show every indication of accelerated recession recently. It can be expected that, if unprotected, these properties will continue to incur losses in the future.

The Trout Run area has been protected by 9 groins that are substantial in construction and effect. Land accumulation behind each is significant even during high lake levels. It can be expected that these structures will offer a measure of protection to the bluff in the future if land cover on the crest does

not change. The Trout Run access has been manipulated by the owner for purposes of commercial growth. Heavy equipment has been used to reduce the bluff to the west of the stream mouth and the borrowed material used to establish a beach area protected by groin structures. The outcome of the alteration on shore configuration will bear future examination.

Point 09-3: The recession rate here has been measured at 38.5 inches annually. Investigation has revealed that the control point passes through a drainage system in relation to a substantial structure on the immediate edge of the bluff. The rate is somewhat questionable as a result. The owner has indicated threat to his property and has offered evidence to this effect.

SECTION 10 Walnut Creek to Wilkins Road, Millcreek Township

The Walnut Creek access area has been reconstituted by major construction over the past five years. The stream mouth has been channelized by major rock structures on both sides; to the west serving as a groin to prevent longshore transport from forming a baymouth bar across the stream mouth, and the structure on the east serving as a protective device for safe access and periodic easterly storms. The effect on the shoreline at this point is illustrated in Figure 23.

A major structure at this point is in peril and concrete forms are being placed as groins to safeguard the structures as well as the access area.

Three residential neighborhoods mark this section: Manchester Heights, Lake Shore, and the Wolf Road area. The bluffs are moderately stable through this section with the exception as noted.

Point 10-1 in the Manchester area can be considered stable. A groin to provide beach materials has protected the bluff for some years.

Point 10-2 is stable with vegetative slopes and little apparent recession.

Points 10-3 to 10-5 are selected points exhibiting an exception to otherwise semi-stable bluffs. Each exhibits strong point recession due to some causative factor. Point 10-4, for example, is on Lake Shore Golf Club property. There is strong indication that material loss is due to accelerated ground water seepage and the lack of vegetation on the crest.

Point 10-6: This section is protected by 6 groins spaced for maximum protection of shore reach. A large volume of sand has been captured, thus protecting the base of the bluff from direct attack.

SECTION 11 Wilkins Road to Montpelier Avenue, Millcreek Township

Bluffs in this section are densely covered by mature trees creating stable conditions. Recession is at the crest mainly, usually due to removal of vegetation at the top for residential landscaping. The combined loss of root structure and ground water control is creating losses at the top, though not severe. The total effect is the production of slopes of lessening steepness. There is evidence that slumping on a large scale has taken place historically, probably 100 years ago or more.

Points 11-1 to 11-4 all have bedrock exposed at the base, varying in thickness to 8 feet. Accelerated recession is taking place at Points 11-3 and 11-4 due to sruface water runoff and ground water seepage from a large field south of the bluff crest. Changing land use here allowing for plant succession should be a retarding influence in the future.

SECTION 12 Montpelier Avenue to Waldameer Park, Millcreek Township

Recession in this area is minimal, with an average rate of 4.55 inches annually. There is strong evidence that slumping on a large scale was a causative factor in producing these slopes. Terracing here is very prominent and, though covered with dense vegetation to include mixed hardwoods, slump blocks are still evident. Activity took place at least 100 years ago. Dendrochronology of trees could produce important time references for this period of accelerated recession for correlation with causative factors active during that time.

Beginning just west of Point 12-1 and extending through Point 12-4, the bluff crest is marked by dense residential development. There is some concern for those structures on the immediate edge though recession is quite insidious.

Beginning at Point 12-3, a broad sandy shelf (representing the roots of the Presque Isle sand spit downshore) protects the bluff and effectively removes the lake as a factor in bluff recession.

NOTE:

Bluff conditions east of the City of Erie differ remarkably from those characteristic of the West County over most sections. The greatest controlling factor for the bluff is the protection offered by bedrock exposures at the base over much of the reach. This bedrock is only minimally exposed in a few sections in the western reach. As noted elsewhere, the exposure has produced unique configurations on the coastline.

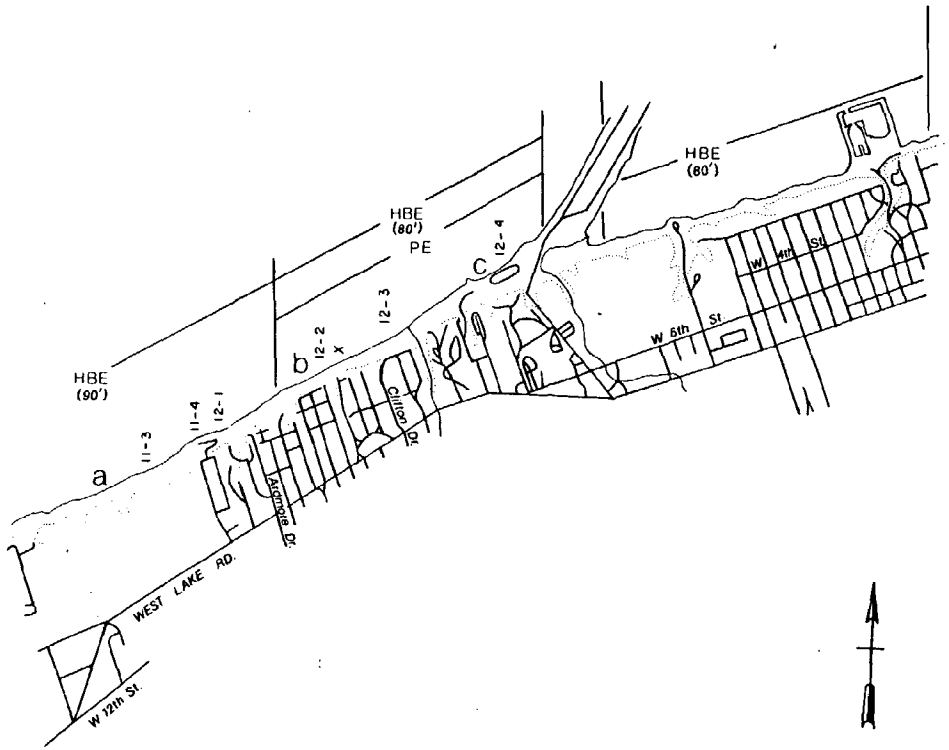
SECTION 13 Hammermill Paper Company to Four Mile Creek, Lawrence Park Township

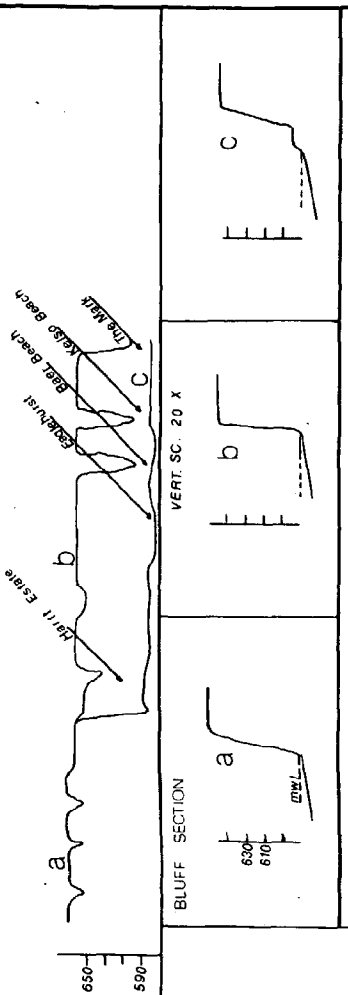
Recession is slight over all points except 13-5. During low lake level, these areas are relatively safe from frontal assaults by lake processes. However, recent high levels and storm activity have removed beach deposits and there is much wave undercutting of bedrock and great evidence that storm waves are eroding materials resting on the bedrock producing a distinctive shelf. Continuation of this phenomena over time, coupled with ground water effects will cause slope failure and result in accelerated recession in susceptible areas.

Point 13-5 represents an area where gullying has produced a channel extending down to bedrock. Headward erosion of this channel has been highly accelerated over time producing point recession of 36 inches annually, a good example of problems associated with man's attempts to drain the plain behind the bluff.

SHORELINE CHARACTERISTICS

Wolf Road to Presque Isle





NOTES

1. HIGH BLUFF WITH GENERALLY STABLE SLOPES
2. HEAVY BEACH COTTAGE DEVELOPMENT WEST OF PRESQUE ISLE
3. EIGHTEEN GROINS; APPROXIMATELY THIRTY INDIVIDUAL BREAKWALLS
4. CRITICAL AREAS:
   - HARTT ESTATES
   - GLENRUADH
   - EAGLEHURST
   - FOREST PARK
   - BAER BEACH
   - BEACHCOMBER COTTAGES
   - PRESQUE ISLE STATE PARK

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- * See Appen. A
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht.

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LAKE ERIE COASTAL HAZARD AREAS

COASTAL ZONE MANAGEMENT PROGRAM

Pennsylvania Department of Environmental Resources

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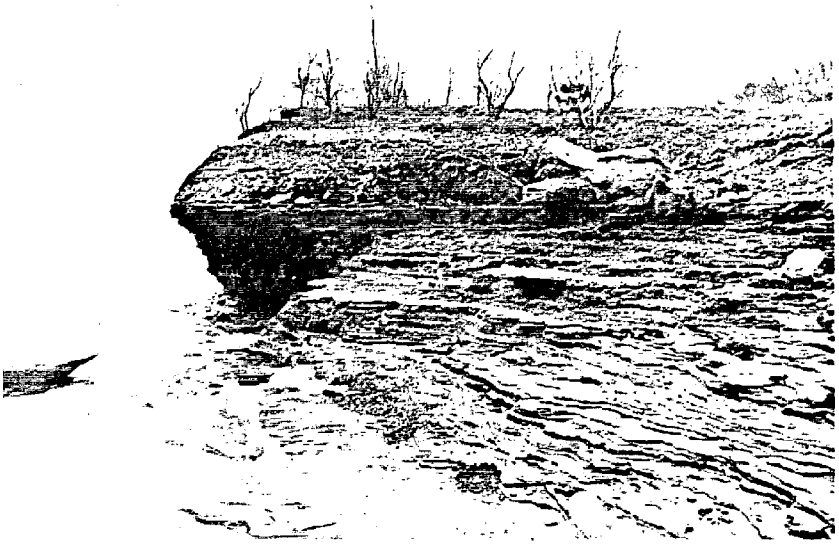
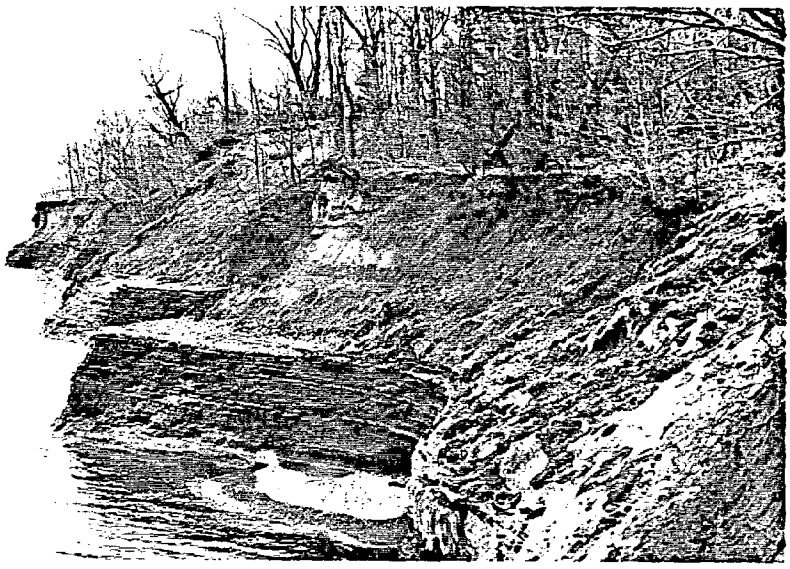


Above and below: Bedrock exposures in Lawrence Park and Harborcreek Township



Above and below: Shelving over bedrock produced differential erosion of bluff - Harborcreek Township

SECTION 14 Lowry Road to Six Mile Creek, Lawrence Park Township

Bedrock exposures through the entire section has the expected influence on recession. Rates are consistently under the overall average of 12 inches annually for the shoreline. There are, however, the same features being produced as in the last section, namely wave undercut, sand removal, and shelfing over bedrock. Again, if conditions on the lake continue over time, recession will become an increasing problem.

SECTION 15 Seven Mile Creek to East of Eight Mil Creek, Harborcreek Township

This entire section is essentially a repeat of the previous section. Recession rates are essentially less than average. Point 15-5 has evidence of accelerated recession, the cause attributable to land cover. The vegetation has been reduced to grasses offering little protection to the bluff crest with the expected results, including a disruption of vegetation on the bluff slope.

SECTION 16 Highmeyer Road to North East Township line, Harborcreek Township

This section is a continuation of the two previous sections. Additional factors include changes in land use through section with resultant impact on recession.

Points 16-1 and 16-2 are within the suburban fringe area with the urban frontier just to the east where agricultural use becomes the dominating use on bluff crest and beyond. Agricultural fields utilized to the very edge of the bluff can have adverse effects on bluff stability. Point 16-4 is an indication of this phenomena, with recession at 19.4 inches annually.

Scalloping of crest with no counterpart on the shore is an indication that the cause lies not with lake processes, but with either natural or man-incuded factors on the bluff face or crest.

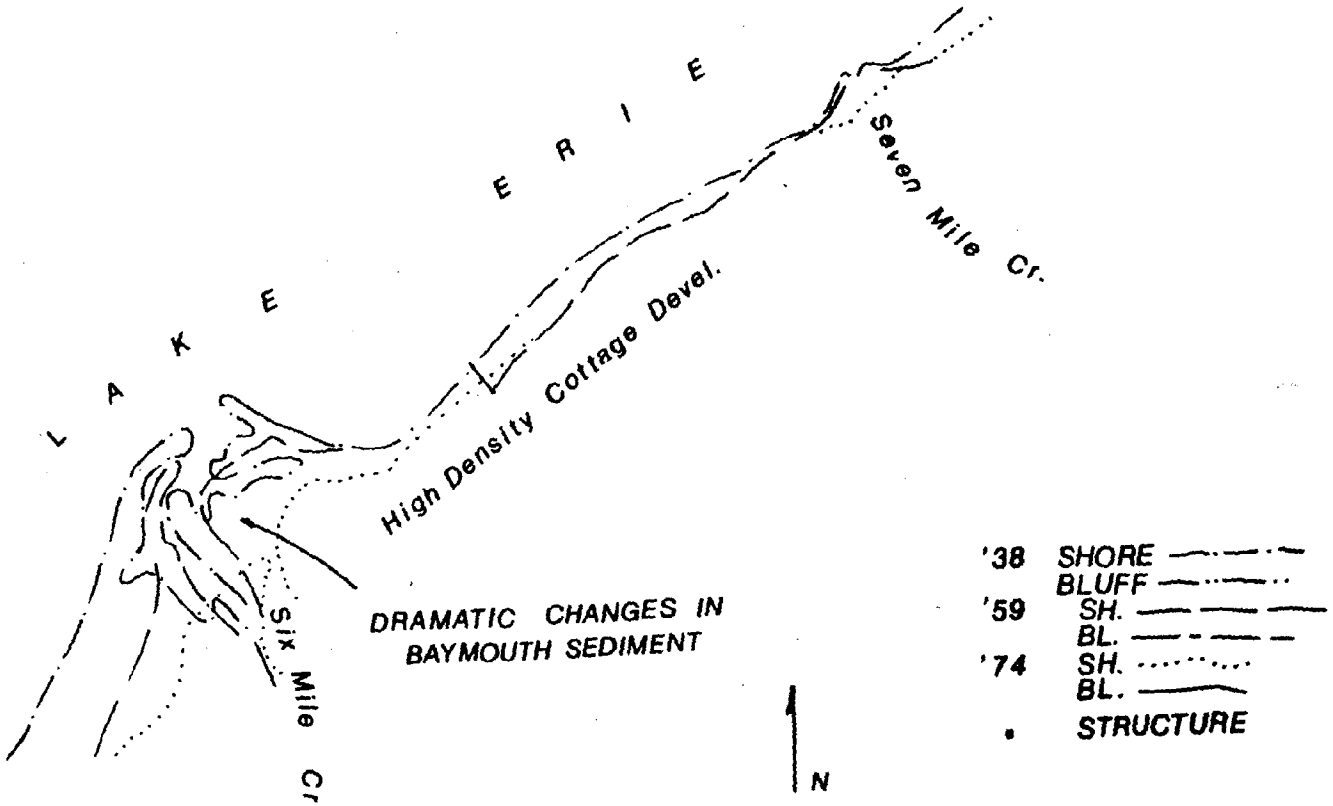
SECTIONS 17 AND 18 North East Township Line to Cemetery Road Area, North East Township

Sections 17 and 18 can be discussed together because of the homogeneity of this region.

Deep scalloping of the bluff crest is the most distinguishing characteristic. The recession rates are not high, but the proximity of State Route 5 gives this area some cause for concern.

It is apparent that the lack of significant natural surface drainage in the area is having an effect on bluff crest. While it bears greater examination, it appears that surface and subsurface flow are producing significant drainage cuts in the bluff. Once started, these cuts can only enlarge in all directions.

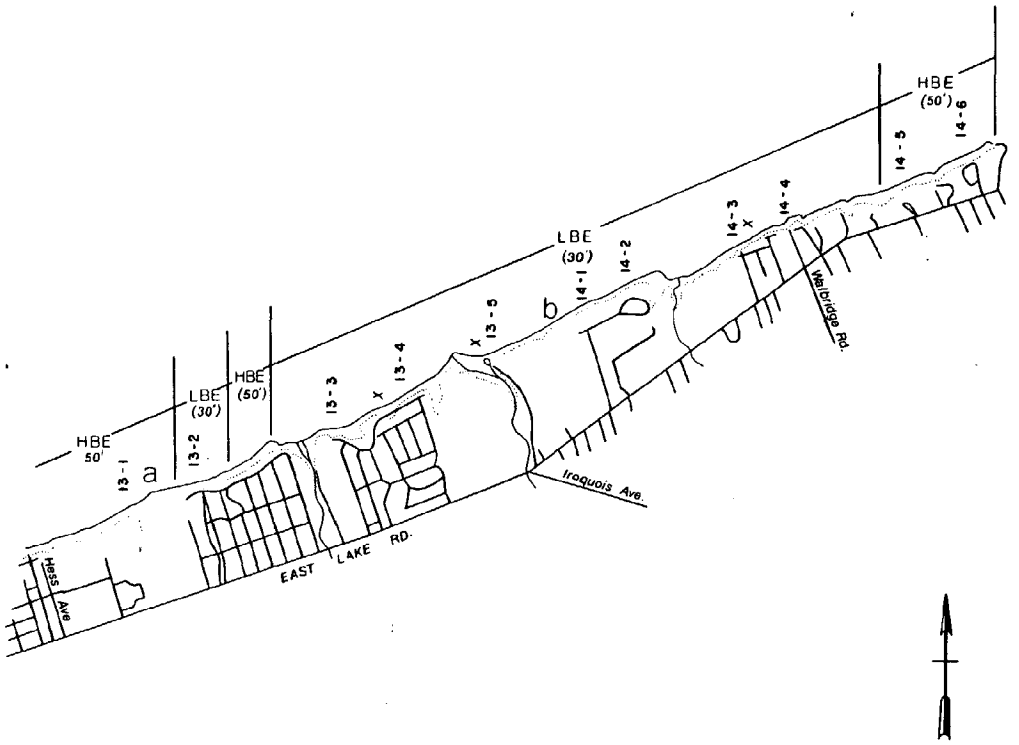
FIGURE 24

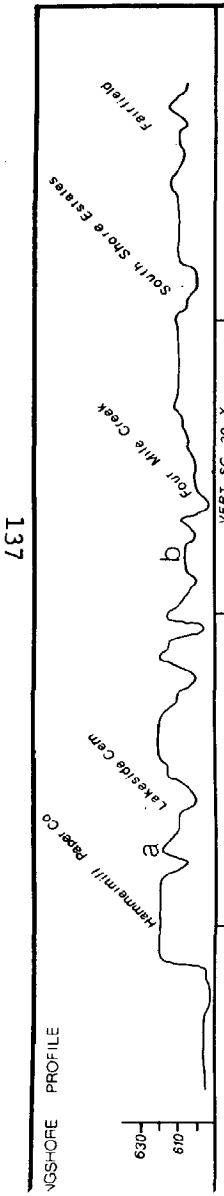


COWELL'S BEACH &
CARTER'S BEACH

SHORELINE CHARACTERISTICS

Hammermill to Fairfield





NOTES

1. VARIABLE, MEDIUM HEIGHT BLUFF; BEDROCK PRESENT
2. INDUSTRIAL, RESIDENTIAL, AND OPEN SPACE USE
3. NO GROINS; FIVE BREAKWALLS; ONE BOAT DOCK
4. CRITICAL AREAS: PORT AUTHORITY BOAT HOUSES; LAKESIDE DRIVE; HAMMERMILL PAPER COMPANY; GENERAL ELECTRIC FISHING CLUB; SUNSET INN

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht.
- * See Appen. A

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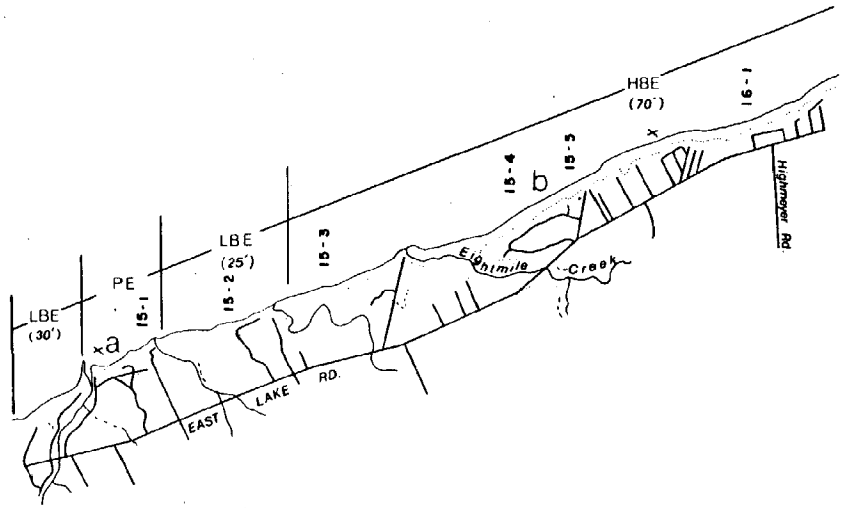
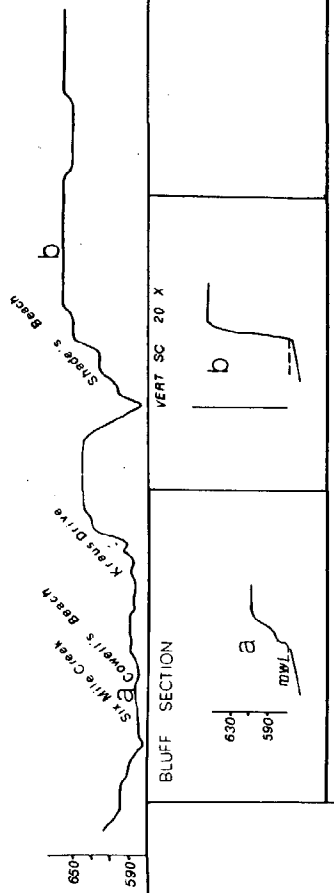
SHORELINE CHARACTERISTICS

Six Mile Creek - Highmeyer R.





NOTES

1. Low bluffs and beach areas in west half of section; high bluffs in east half of section
2. Cottages in west section; residential areas in east section
3. Four groins; one breakwall; two boat docks
4. Critical areas: Cowell's Beach
   Carter's Beach
   Kraus Drive

LEGEND

01-1	Photogrammetric Control	LBE	Erodible Low Bluff
X	Survey Control	PE	Erodible Plain
	Approx. Bluff Line	(40')	Minimum Ht.
a	Section Location		
*HBE	Erodible High Bluff		

* See Appen. A

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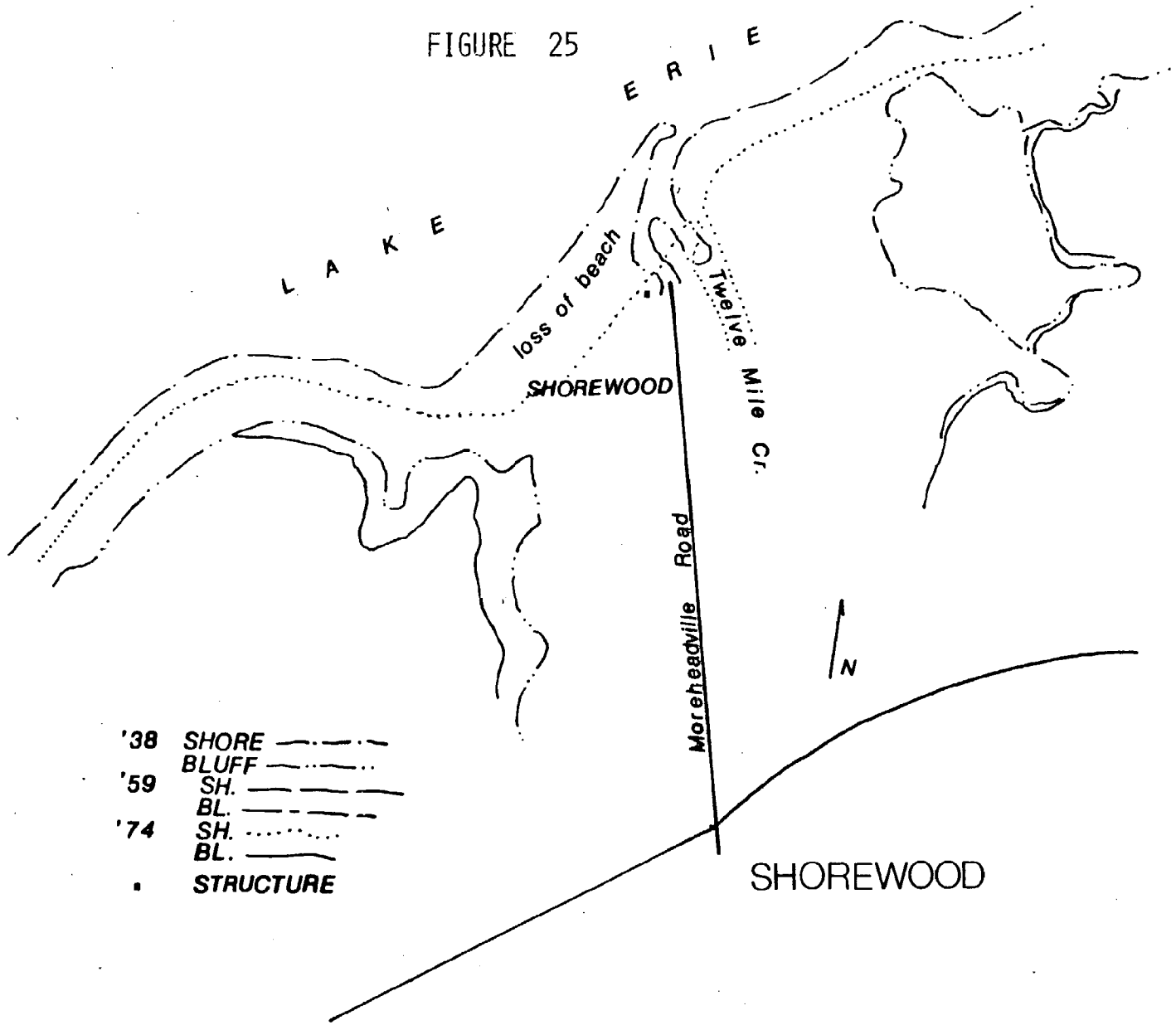
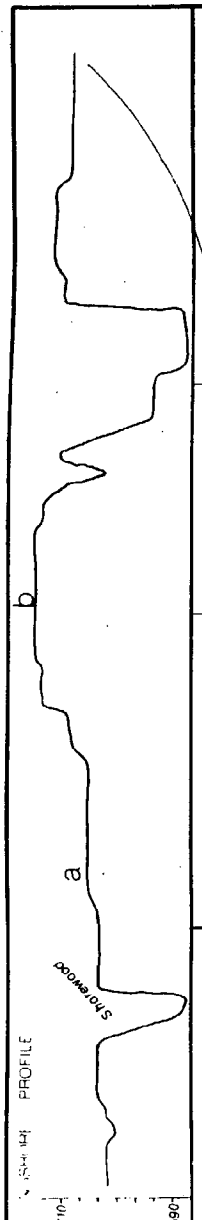
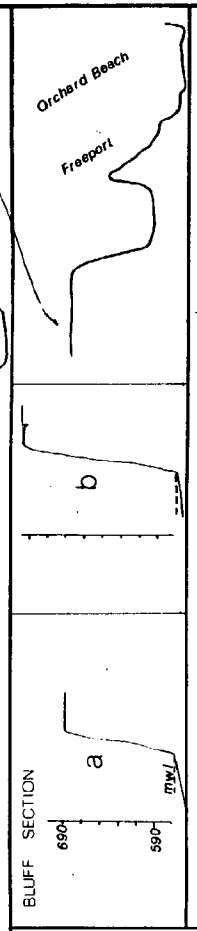
FIGURE 25

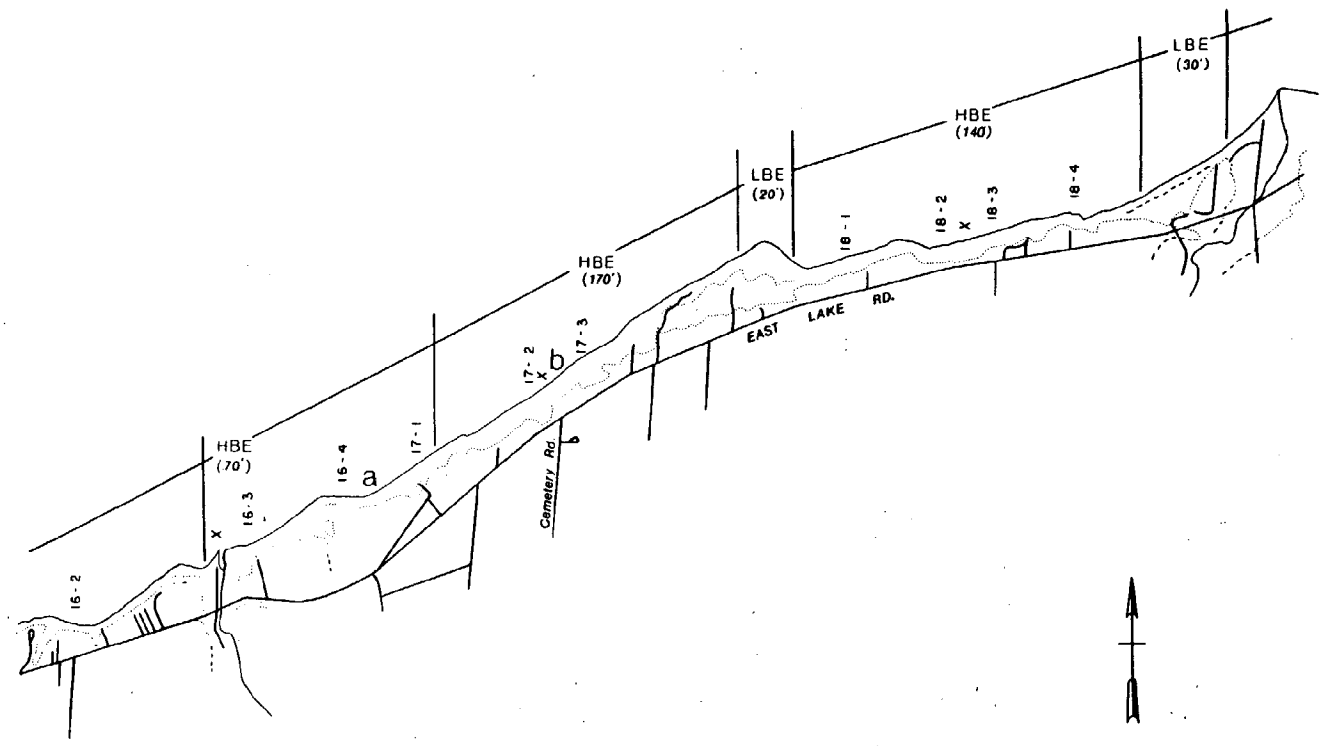

LAKE ERIE
loss of beach
SHOREWOOD
Twelve Mile Cr.
Moreheadville Road
N
'38 SHORE
BLUFF
'59 SH.
BL.
'74 SH.
BL.
STRUCTURE
SHOREWOOD

SHORELINE CHARACTERISTICS

Twelve Mile Creek to Orchard Beach - Freeport







NOTES

1. HIGHEST BLUFFS IN THE COUNTY
2. AGRICULTURAL AND RESIDENTIAL AREA
3. NO GROINS; ONE SEAWALL AT SHOREWOOD
4. CRITICAL AREAS: SHOREWOOD INN/COTTAGES
   BRICKYARD ROAD

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht.

* See Appen. A

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Again, the evidence is strong that recession is not being produced by lake related processes, but by processes active on slope, and behind. The shore does not exhibit the same degree of scalloping; however, there is evidence in this section, as well as in sections immediately east and west, of accelerated erosion at the base of the bluff. A steep, almost vertical face is being produced, essentially by storm waves. As material is removed from the base, the slope will become increasingly instable, leading ultimately to slope failure.

SECTION 19 Sixteen Mile Creek to Twenty Mile Creek, North East Township

Section 19 is marked by bedrock control producing reduced recession rates through the section. The low bluff, with significant drainage channels, presents a major change in conditions just west of this area. The area is used extensively as summer cottage development areas because of easy access to the water's edge. Control of such a bluff should be relatively simple if conditions on the lake persist. High water is taking its toll in beach materials and structural damage at the present time.

Point 19-4 is a measure of shore recession with the indication being little net loss over time.

SECTION 20 Twenty Mile Creek to New York State Line

The bedrock disappears east of Twenty Mile Creek and so does reduced recession. Shore erosion at Point 20-1 is severe for the East County at 14 inches annually and recession of the low bluff at Point 20-2 reaches 21 inches annually. This accelerated recession rate continues into New York State and is cause for major concern there.

At both points, there is a threat to State Route 5 within the next 40 years.

SUMMARY

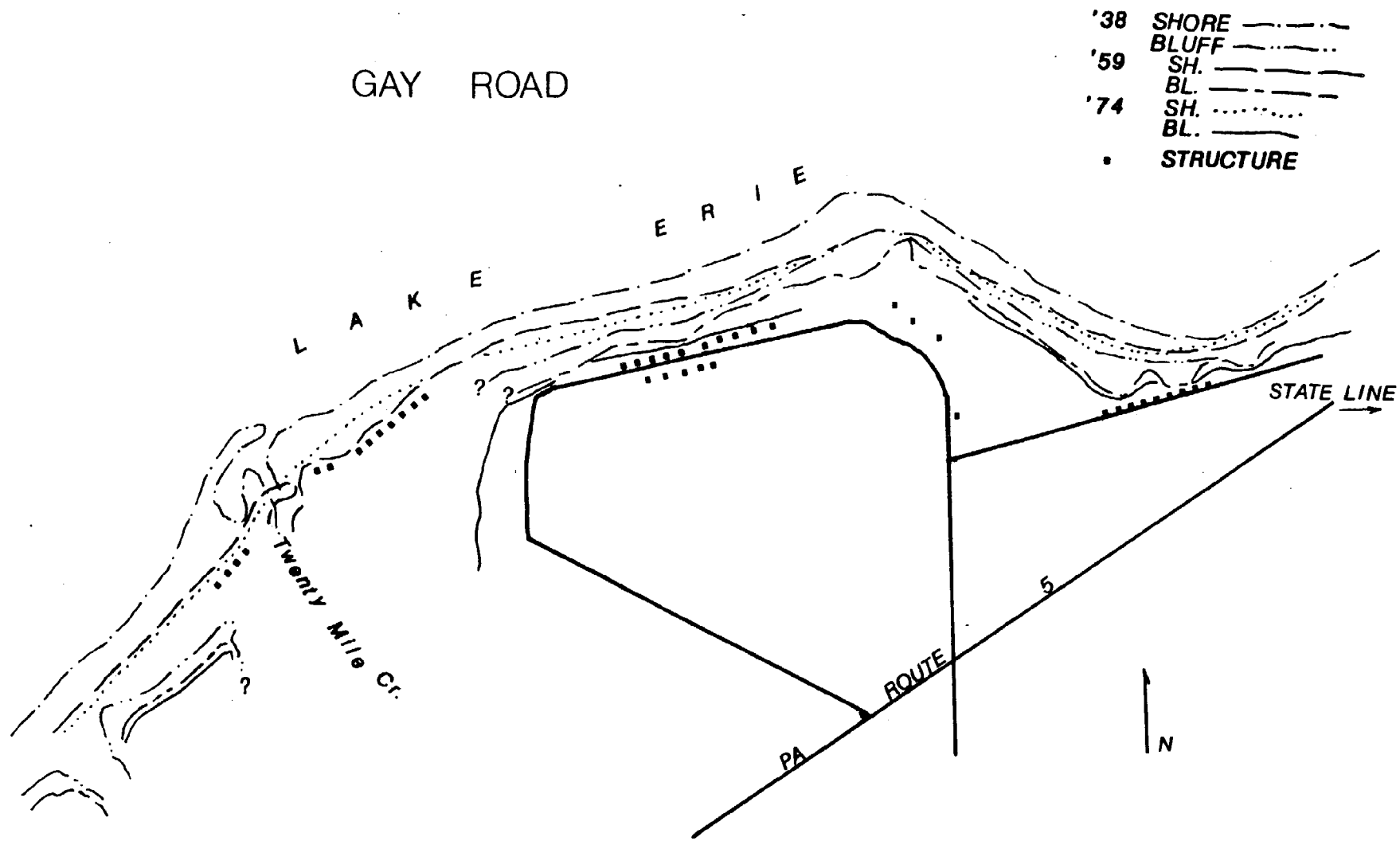
Assuming a small margin in error in recession rate measurement and with the averaging of data, a clear picture emerges for conditions in the Coastal Zone.

Figure 28 is a plot of average rates measured by section and shows not only variation in causative factors, but the reduced recession of the East County area.

Recession is a phenomena that must be considered at every planning stage for Coastal Zone Management. Nowhere on the coast is recession "zero" over time. There are certain safe areas with greatly reduced rates due to some controlling factor. The purpose of this report is to essentially identify critical hazard areas, and these we think are clearly defined by the accelerated recession rates apparent in many areas. The other factors considered in critical hazard zone delineation are cited elsewhere in this report.

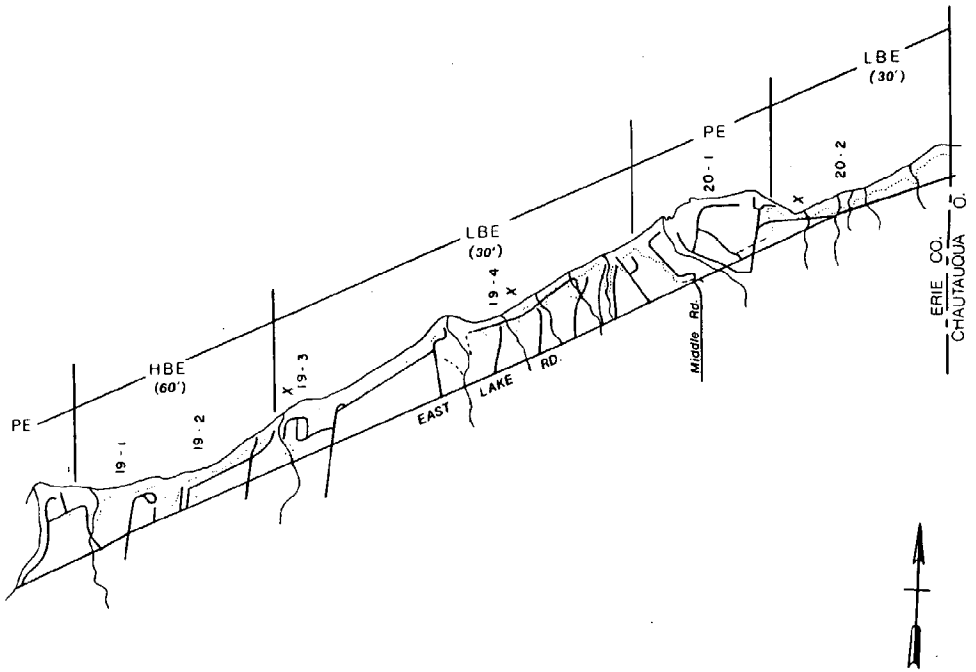
It is clear that the following are factors contributing to accelerated

FIGURE 26

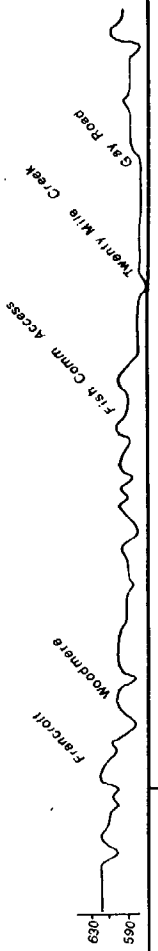

GAY ROAD
'38 SHORE
BLUFF
'59 SH.
BL.
'74 SH.
BL.
STRUCTURE
L A K E E R I E
STATE LINE
Twenty Mile Cr.
ROUTE 5
PA
N

SHORELINE CHARACTERISTICS

ORCHARD BEACH TO N. Y. LINE



SHORE PROFILE



BLUFF SECTION

n.a.

NOTES

1. Low bluff and beach area
2. Heavy cottage and residential development
3. No groins; steel drum breakwall at Orchard Beach; several individual breakwalls
4. Critical areas:
   - Sunset Beach
   - Orchard Beach
   - Francroft
   - Dewey Road Fish Commission Access Area
   - Hidden Lane
   - Twenty Mile Creek

LEGEND

- 01-1 Photogrammetric Control
- X Survey Control
- Approx. Bluff Line
- a Section Location
- *HBE Erodible High Bluff
- LBE Erodible Low Bluff
- PE Erodible Plain
- (40') Minimum Ht.
- * See Appen. A

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COASTAL ZONE MANAGEMENT PROGRAM

recession rates:

1. high lake levels
2. storm conditions and frequency
3. bluff structure (bedrock, tills, lacustrine clays and sands)
4. wind direction and strength
5. sediment loading by streams
6. material availability in longshore transport systems
7. ground water seepage
8. sheet runoff on bluff face surface
9. runoff from area behind bluff crest
10. vegetation on crest and slope
11. beach deposits at base
12. occurrence of ice on lake (essentially absent for the past two years)
13. frost action on bluff
14. gravity
15. control structures on shoreline (groins, seawalks)
16. stream dissection
17. land use on bluff crest
18. induced drainage onto bluff slope by septic outfall, storm drains and highway drainage, as well as buried drainage tiles in conjunction with agricultural use

An examination of these factors as variables and the interaction between them are found elsewhere in this report.

Because of the variables involved, it must be stressed that recession rates determined are only long term averages for future planning. It cannot be assumed that the rates are constants or that rates are applicable over broad areas east and west of the photogrammetric controls. Each parcel of land must be carefully analyzed according to the variables present and its use then planned to be in conformance with the least possible threat to structure or environment. It is dangerous to use a 12-inch annual recession rate as a measure for any critical local planning determination. An analysis of the recession rate data reveals that the average is in no way representative of recession over most points.

FIGURE 27

SUMMARY OF RECESSION RATES
BY SECTION

SECTION	X / Y(1)	r(2)
1	151.7 / 8	18.96
2	139.3 / 8	17.40
3	87.7 / 4	21.90
4	12.3 / 2	6.15
5	46.3 / 2	23.50
6	95.1 / 5	19.02
7	64.4 / 4	16.10
8	17.4 / 4	4.35
9	82.5 / 5	16.50
10	99.2 / 6	16.50
11	56.4 / 4	14.10
12	18.2 / 4	4.55
13	57.1 / 5	11.42
14	45.4 / 6	7.57
15	31.9 / 5	6.38
16	32.7 / 4	8.18
17	34.7 / 3	11.57
18	26.3 / 4	6.58
19	22.0 / 4	5.50
20	35.0 / 2	17.50

(1) X = Total average recession rate by Point
Y = No. of Points in section

(2) 4 = Annual recession rate in inches over period of record (1938-1974/75

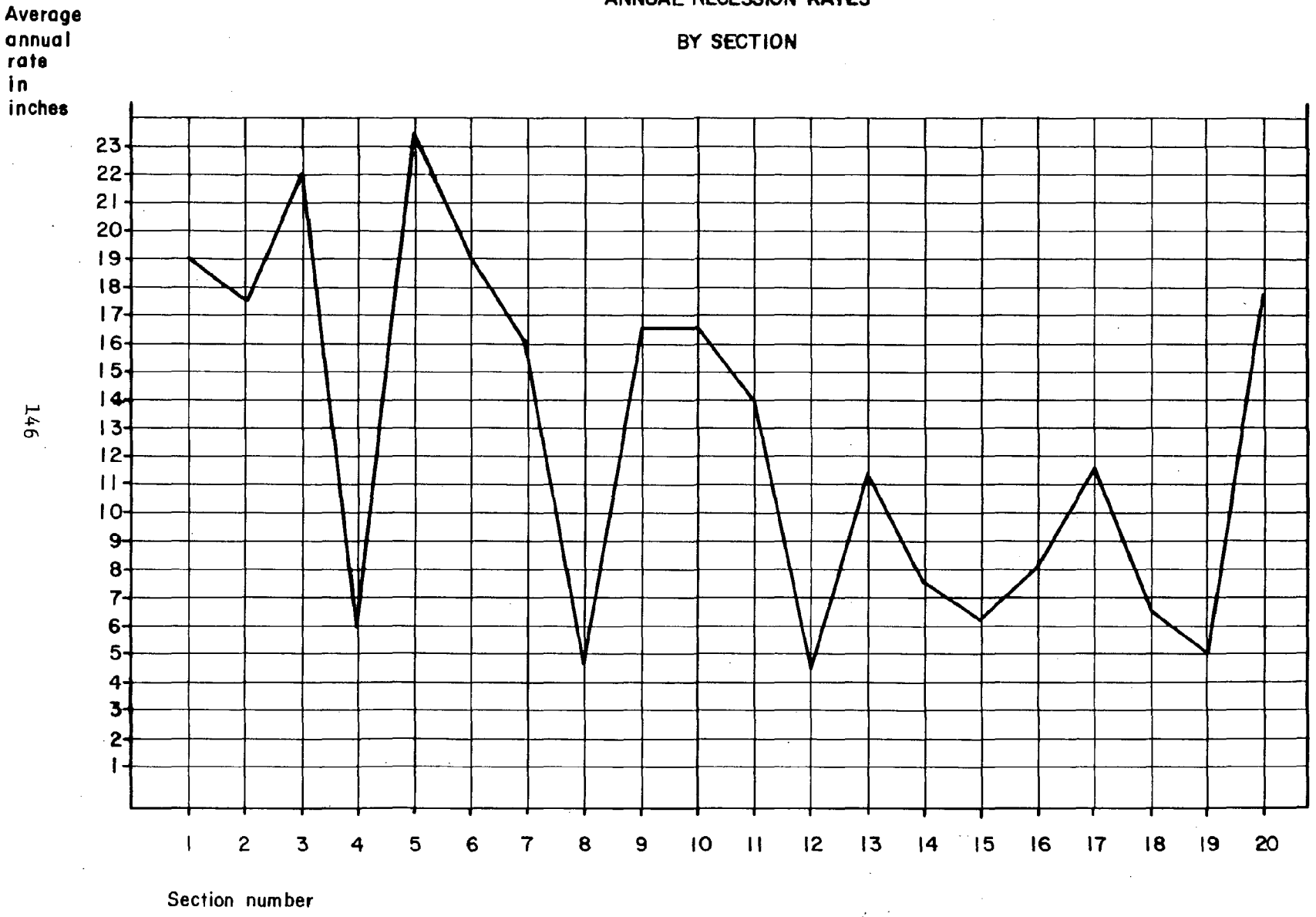
Average West County - 14.89" annual average (Sections 1 thru 12)
Average East County - 9.34" annual average (Sections 13 thru 20)

Total Erie County Average - 12.12" annual average

FIGURE 28

ANNUAL RECESSION RATES

BY SECTION



SECTION 6
HAZARD AREA SUMMARY

HAZARD AREA CLASSIFICATION

Before any shoreline can be classified in terms of how susceptible it may be to erosion and/or recession, a careful definition of terms and the factors affecting selection of hazard areas must be provided. We have found by interview and by responses on the survey questionnaire that most property owners feel that they have experienced "severe erosion" because of loss of beaches, destroyed boathouses, displaced stairways, and water pipes. To them it represents serious problems. The scope of this study, however, is to determine those areas where extreme disruption of land and structure is likely to occur. Therefore, there may be some omissions of isolated problems; for example, single lots on Lakeside Drive in Erie and Wolf Road in Millcreek. Furthermore, there was little attempt in this study to analyze the recession and erosion data in conjunction with land values or structural values. As work continues and as citizens become more involved in the Coastal Zone Management Program, a more definitive classification should occur.

In general a reach or area of shoreline can be identified as a critical hazard area if any of the following criteria are met:

1. If the shore zone is subject to Lake flooding of land or structures or stream flooding caused by a bay mouth bar.

2. If the area has experienced severe loss of shoreline by erosional processes and/or high water and there are structures built in the shore zone that have come under extreme attack.

3. If the bluff is experiencing a recession rate that is likely to exceed an annualized average of 1.5 feet over a period of years. These areas are considered critical hazard areas regardless of the present density of development as a guide for future planning.

4. Those areas experiencing only moderate recession rates, but containing structures near the bluff crest.

5. In general, if the area is expected to suffer significant damage to land and structures within the next ten years.

Within the context of the above, those areas identified as being critical hazard areas are summarized in this section. Other areas were further classified either moderate hazard or limited hazard.

Since recession is a phenomenon that can be expected to continue through time, sections now classified as moderate may in fact become critical in the span of a few years due to changes in any of the factors causing erosion or recession. The following definitions were used for moderate and limited:

(a) Moderate Hazard Area - areas that could become potentially critical within 25 years (i.e., by the year 2000).

(b) Limited Hazard Area - areas that are not likely to be affected over the next 25 years because of limited recession or definite stability in conditions.

The above classifications are given with the understanding that the range of conditions that have existed during the past 35 years will occur during the next quarter century. It is not possible to predict the variables producing accelerated periods of recession during that time. On the one hand, water level conditions on Lake Erie could moderate to the point that little recession would occur over the next 25 years. On the other hand, if water levels remain high and moderate winters provide little ice cover, recession rates could continue to accelerate and make the entire shoreline extremely critical and hazardous. Therefore, any prediction on future activity must be based on the average of conditions in the past.

There are a total of 109 areas or sites which have been identified. There are areas within each section that are relatively small in extent and vary with the overall classification. This section of the report uses place-name designation of hazard areas. Included are all major residential areas and all large individual sites, such as camps, parks, churches, motels, and industrial sites. Of these sites, forty-four (44) have been designated critical; fifty-one (51) as moderate; and ten (10) as limited. On the following page, there is a summary of the hazard areas by township.

The Townships of Springfield, Millcreek, and North East contain the most hazardous sections. Springfield has long reaches of nearly vertical bluffs that are unprotected by bedrock, vegetation, or man-made control structures. However, the shoreline contains the least number of permanent residences; the land is used mainly for summer residences and camps.

Millcreek Township has a number of critical areas because of the large beach cottage developments from Montpelier Avenue to Kelso Beach. Also, Presque Isle State Park has been listed in the Millcreek section.

North East Township is critical because of the intense residential development on the beaches and low bluffs from Freeport Lane (State Route 89) to the New York State Line.

In the less hazardous townships, the critical areas are primarily at the mouths of streams where the hazard is flooding and beach erosion. In Girard Township the problems include recession as well. The critical areas are the mouth of Elk Creek, Lake Erie Community Park, and two private residential areas. In Fairview Township, Walnut Creek is the most hazardous area.

In the City of Erie, the Port Authority boathouses near East Avenue and the site of Hammermill Paper Company are the significant critical areas. In Lawrence Park Township, the Lakeside Drive area and the General Electric Fishing Club have been designated critical. In Harborcreek Township, the low lying cottage areas are the most critical; namely, Cowells' Beach, Carter's Beach, Kraus Drive, and the Shorewood area.

HAZARDS TO ROADWAYS

There are presently no public roads in critical danger. There are

FIGURE 29

HAZARD AREA SUMMARY

TOWNSHIP	CRITICAL	MODERATE	LIMITED	TOTAL
Springfield	10	4	--	14
Girard (including Lake City)	5	7	--	12
Fairview	1	10	--	11
Millcreek (Lakeshore only)	8	6	--	14
Erie (Lakeshore only)	3	4	4	11
Lawrence Park	2	2	1	5
Harborcreek	4	13	5	22
North East	11	5	--	16
	44	51	10	105

FIGURE 29 A

HAZARD AREA SUMMARY

(Longshore Distance)

TOWNSHIP	CRITICAL	MODERATE	LIMITED
Springfield	4.2 miles	3.3 miles	0.0 miles
Girard (including Lake City)	1.3	3.5	0.0
Fairview	0.3	4.8	0.0
Millcreek (Lakeshore only)	0.3	2.1	0.0
Erie (Lakeshore only)	0.7	0.6	0.8
Lawrence Park	0.3	0.8	0.1
Harborcreek	0.7	5.8	0.0
North East	4.4	4.1	0.0
Sub-total	12.2	25.0	0.9
Presque Isle State Park	8.0	0.0	0.0
TOTAL (Lakeshore)	20.2 miles	25.0 miles	0.9 miles

several private access roads which are in critical danger; these are usually dirt roads which run parallel to the lake and in back of cottages which front on the lake.

There are a number of access roads, both public and private, which terminate at or near the shoreline. These access roads are being eroded away at the same rate as the adjacent property. However, their basic function is not being impeded, except in the case of a few roads used as boat ramps.

Only if severe conditions continued over a long period would public roads be endangered by the year 2000. These roads are: Old Lake Road in Springfield Township; two sections of State Route 5 in Harborcreek Township; several subdivision roads in North East Township; and several sections of State Route 5 North East Township. However, such severe conditions are not anticipated at the present time.

HAZARD AREA PROTECTION MEASURES

Excluding the groins and breakwalls on Presque Isle, there are approximately 90 groins and 55 seawalls protecting the Erie County shoreline (See Township Summary on following page). Most of these control structures are protecting private property and were built by the property owners. Public structures are at the Springfield Township Beach on Eagley Road, Walnut Creek, East Avenue Boat Ramp, Lawrence Park Boat Dock, and Shades Beach County Park.

Most of these control structures, both public and private, are now offering some degree of protection to property. However, most structures manifest the weaknesses typically found in all control structures. That is, groins generally protect the property to the west because the littoral drift in this section of Lake Erie is from west to east. Sand and gravel are thus trapped on the west side of the groin. But because there is no material supplied to the east side of the groin, there is generally accelerated beach erosion and bluff recession to the east. This phenomenon was observed throughout the county, with outstanding examples at Camp Fitch, Walnut Creek, the Millcreek cottage section, and Kraus Drive in Harborcreek.

Breakwall effectiveness depends mainly on size and depth of placement. Small walls are easily overtopped and undercut by waves. Even large walls that are not placed deep enough to resist undercutting can be easily weakened by waves.

There are significant seawall structures, both large and small, in the following areas: Ellis Road and Eagley Road in Springfield Township, the Millcreek beach cottage area, Hammermill Paper Company, Shorewood Inn in Harborcreek, and Orchard Beach in North East.

FIGURE 30

SUMMARY OF CONTROL STRUCTURES

TOWNSHIP	GROINS	WALLS
Springfield	23	4
Girard (including Lake City)	15	3
Fairview	27	2
Millcreek (Lakeshore only)	18	30
Erie (Lakeshore only)	--	7
Lawrence Park	1	--
Harborcreek	6	3
North East	--	6
TOTALS	90	55

SUMMARY OF HAZARD AREAS
BY TOWNSHIP AND PLACE NAME

The following section contains a listing of hazard areas in each township using the classifications previously defined. There are also maps of each township which are copies of USGS topographic maps. The hazard areas are designated on each map using the following code:

C CRITICAL HAZARD AREA

M MODERATE HAZARD AREA

L LIMITED HAZARD AREA

SPRINGFIELD TOWNSHIP

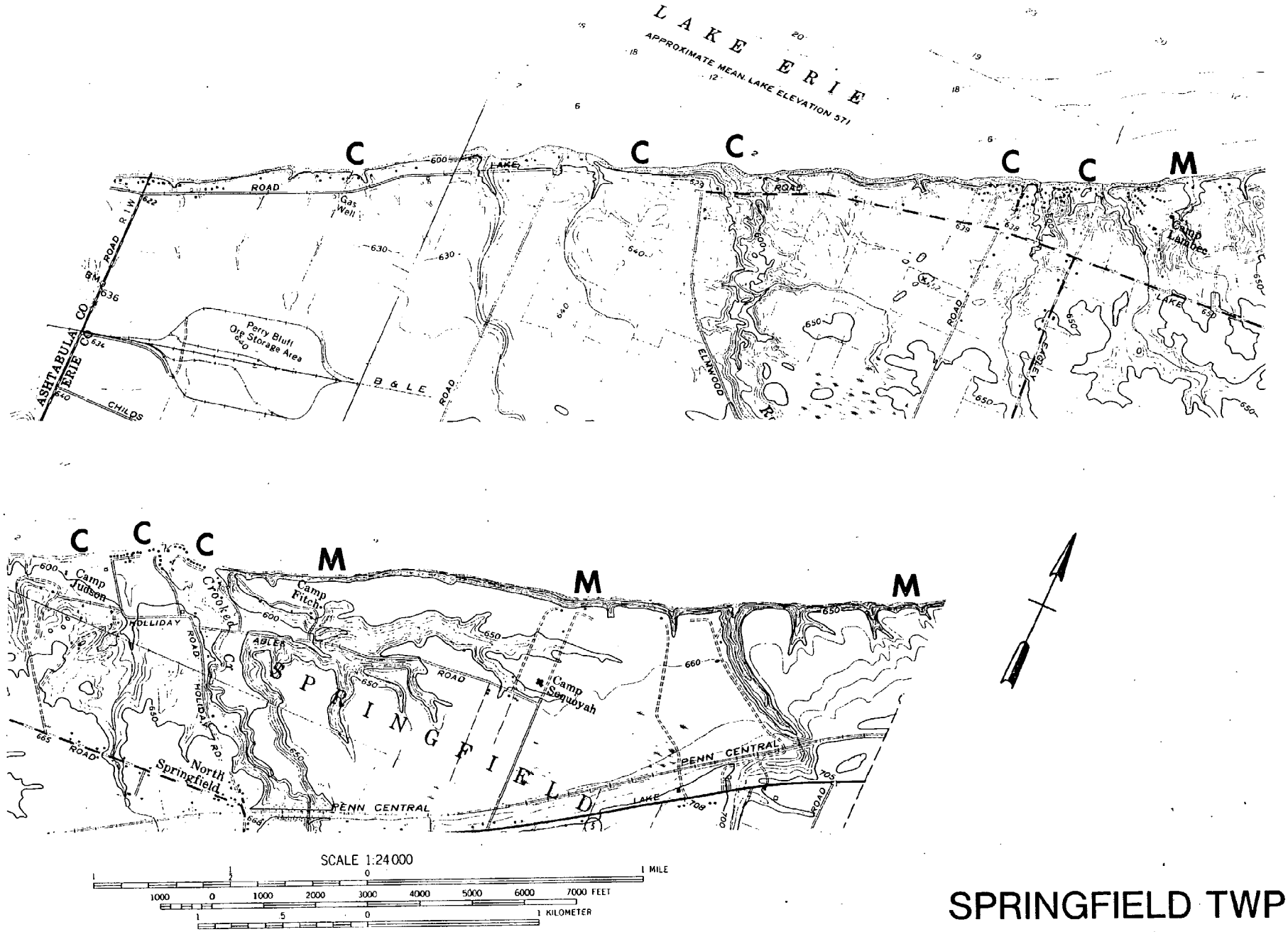
HAZARD CLASSIFICATION	AREA	COMMENTS
Critical	State Line to Rudd Road	Severe accelerated recessi
Critical	Rudd Road to Elmwood Road	Severe accelerated recessi
Critical	Raccoon Creek County Park	Loss of beach and vegetati
Critical	Ellis Road--Summer City	Recent recession forcing structural setback
Critical	Eagley Road	Individual structures subj to severe storm attack
Critical to Moderate	Springfield Township Beach (Eagley Road)	Loss of beach and vegetati
Moderate	Camp Lambec	Structure on crest of bluf but camp protected by groi
Critical to Moderate	Dan's Beach	Low bluff; rapid recession but structures are mobile homes
Critical	Camp Judson	Low bluff, no protection; rapid recession

SPRINGFIELD TOWNSHIP, continued

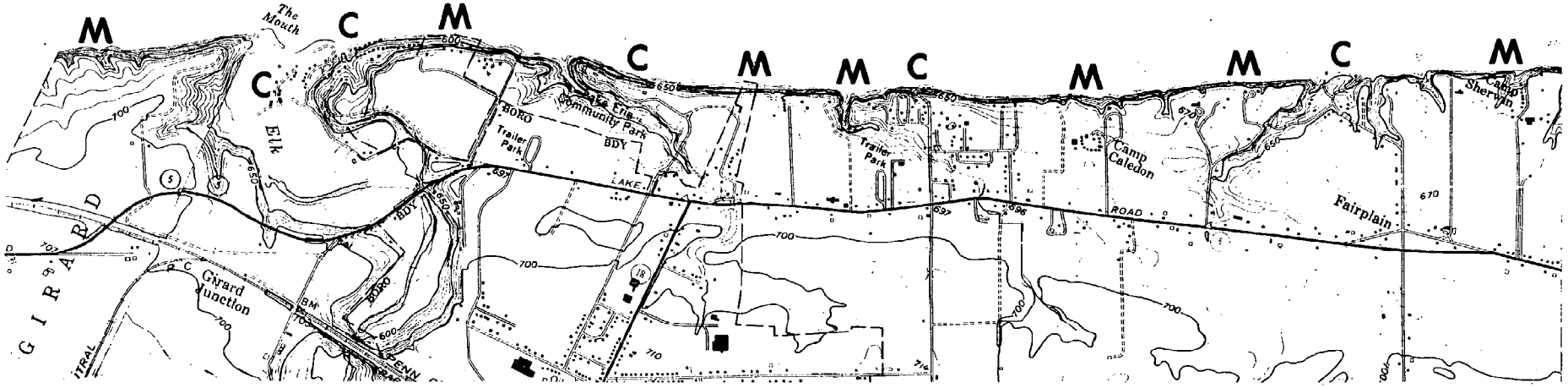
HAZARD CLASSIFICATION	AREA	COMMENTS
Critical	Holliday Road--Holliday Shores	Flooding plus recent rapid recession and loss of trees
Critical	Crooked Creek--Miles Beach	Flooding
Moderate	Camp Fitch	Protected by groins but one critical area of slumping due to end of groin field
Moderate	Camp Sequoyah	Two areas of significant recent slumping
Moderate	Penelec Property	Headward erosion of drainage channels endangers area behind crest

GIRARD TOWNSHIP
(including Lake City Borough)

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Penelec - (Proposed Power Plant Site)	Some slumping evident
Critical	Elk Creek - (Proposed Pennsylvania Fish Commission Access Area)	Flooding
Critical	Elk Creek--Bluff Cottages	Rapid recession, improper drainage
Moderate	Fiesler Drive (Lake City)	Beach loss; toe erosion
Critical	Lake Erie Community Park	Severe slumping
Moderate	Richardson's Cement Works (Lake City)	Threat to conveyor system



SPRINGFIELD TWP.



SCALE 1:24 000

1 MILE
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1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 570.5 FEET

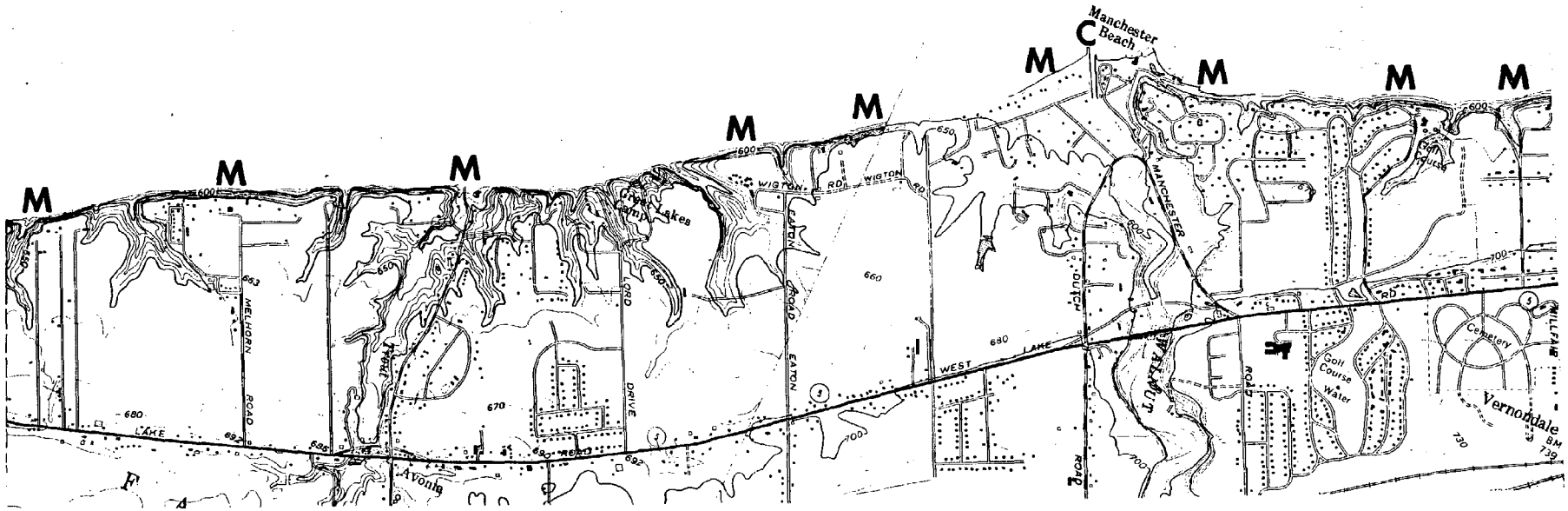
GIRARD TWP.

GIRARD TOWNSHIP, continued

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Erie Lakelands Association	Severe slumping
Critical	Culbertson Road	Two cottages at base o bluff subject to damag
Moderate	Camp Eriez (formerly Caledon)	Beach loss
Moderate	Godfrey Road	Recession/slumping
Critical	Godfrey Run/Fairplain Road	Significant recession individual sites
Moderate	Camp Sherwin	

FAIRVIEW TOWNSHIP

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Hartley Road/Beach Drive	
Moderate	Melhorn Road/Erie Shores	Loss of beach and boat houses
Moderate	Trout Run/Avonia Road	Protected by groins
Moderate	Lord Road/Eaton Road	
Moderate	Camp Notre Dame	
Moderate	Manchester Beach	Low lying beach, exten sand accumulation behi Walnut Creek channel g



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1 5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

DATUM IS MEAN SEA LEVEL

DEPTH CURVES IN FEET—DATUM IS LOW WATER 570.5 FEET

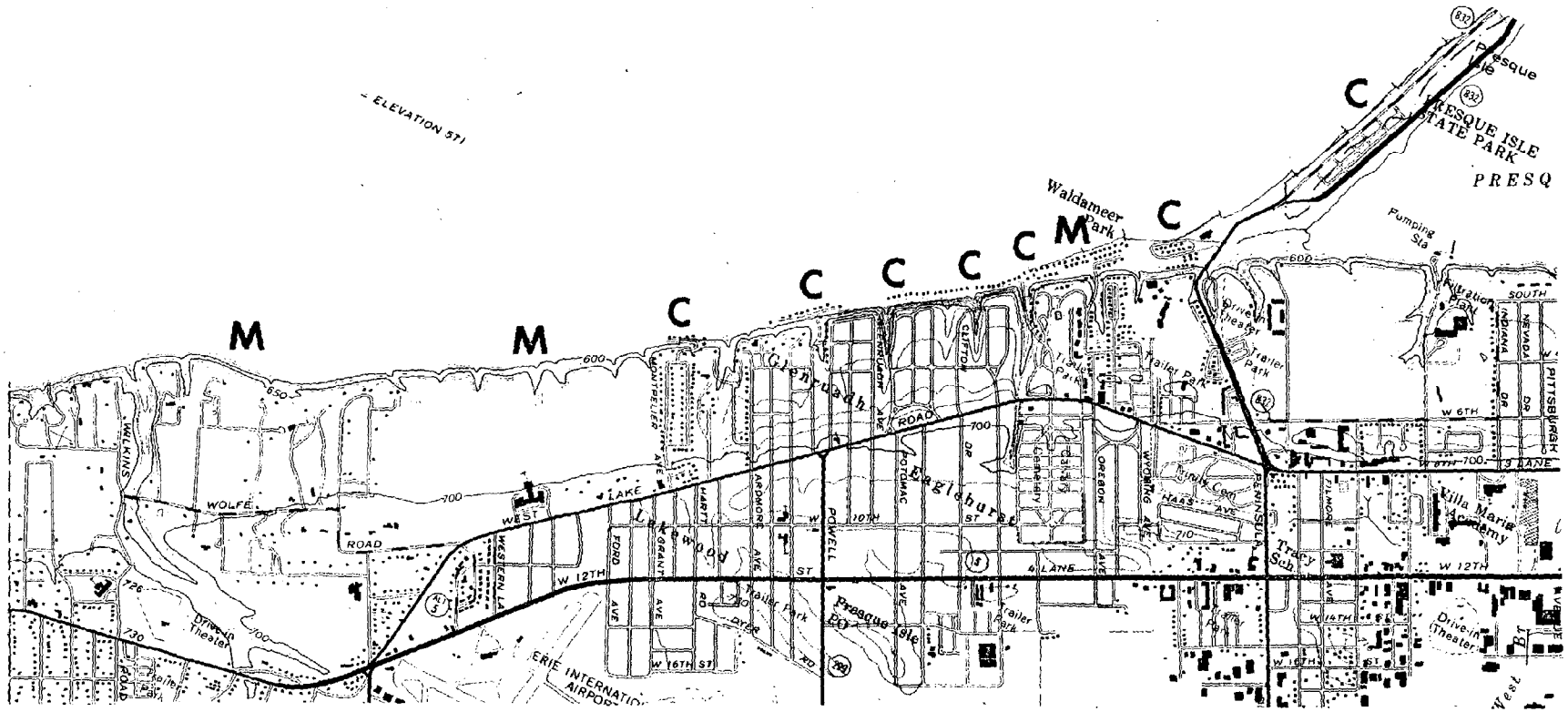
FAIRVIEW TWP.

FAIRVIEW TOWNSHIP, continued

HAZARD CLASSIFICATION	AREA	COMMENTS
Critical	Walnut Creek - (Pennsylvania Fish Commission Access Area)	Significant alteration to beach face due to channelization and groin structu
Moderate	Manchester Heights	
Moderate	Lake Shore District	
Moderate	Lake Shore Country Club	Recent slumping in one small area
Moderate	Colony Subdivision	

MILLCREEK TOWNSHIP
(Lakeshore Only)

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Wolf Road--Wilkins Run	
Moderate	Scott Estate (Westlake Junior High School	
Critical	Hartt Estates--Montpelier Avenue	
Critical	Glenraudh (The Willows)	High water levels here cause severe beach loss and property damage to cottages at base of bluff
Critical	Eaglehurst	
Critical	Forest Park	
Critical	Baer Beach	



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1 MILE

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CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 570.5 FEET

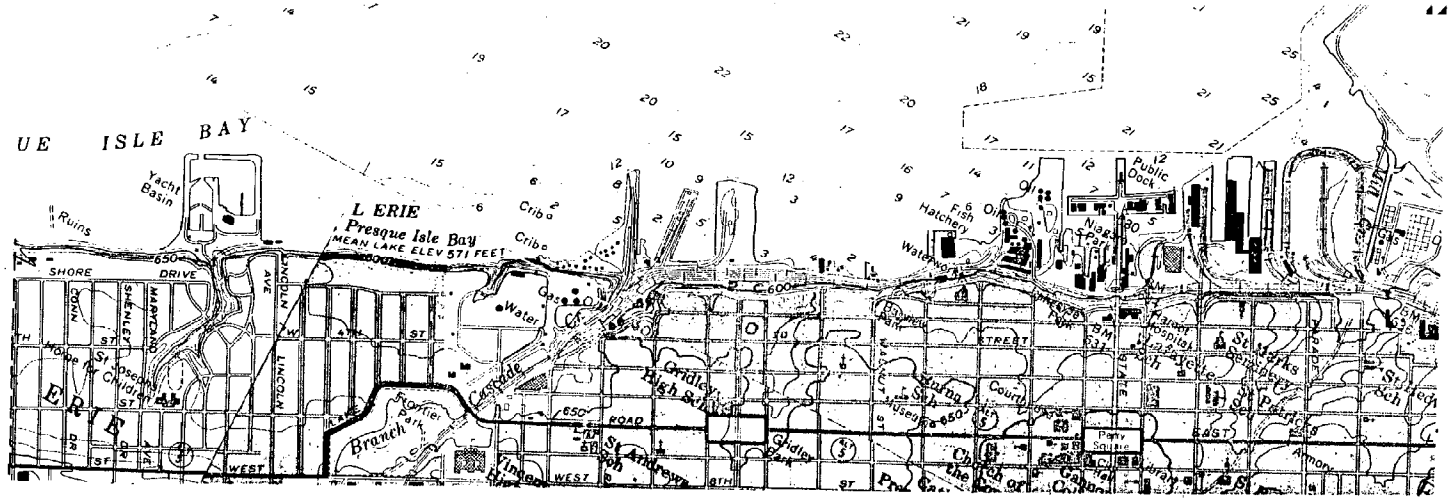
MILLCREEK TWP.

MILLCREEK TOWNSHIP, continued

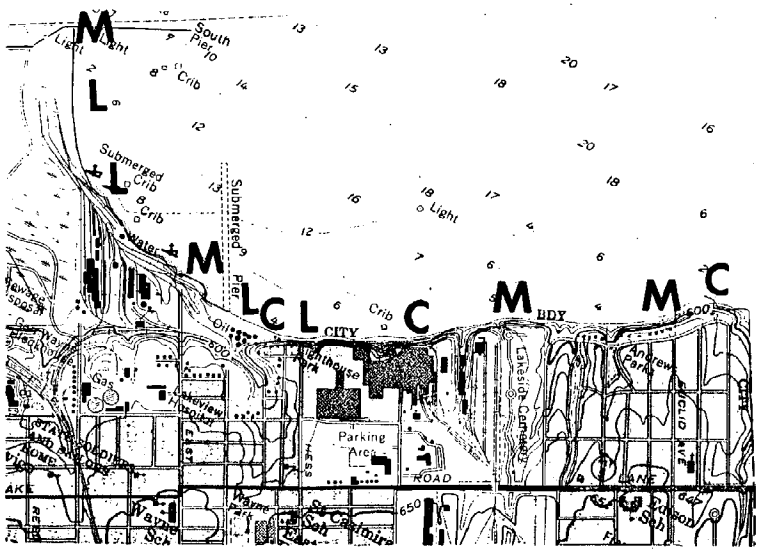
HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Kelso Beach Hotel	Protected by broad beach built by groin
Moderate	Kelso Beach	
Moderate	Waldameer Park	Large structure on bluff
Critical	Beachcomber Cottages	Flooding behind beach berm
Moderate	The Mark Restaurant	Protected by groin
Critical	Presque Isle State Park	See Corps of Engineers reports
Critical	U. S. Coast Guard Station	Flooding

CITY OF ERIE
(Lakeshore Only)

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	South Pier--Port Authority	Protected by Presque Isle
Limited	Proposed Diked Disposal Area--Army Corps of Engineers	Same as above
Limited	Koppers Company--Coke Plant	Same as above
Moderate	East Avenue Boat Ramp/Port Authority (including proposed expansion)	Flooding
Limited	Gulf Oil Tanks--East Avenue	Protected by seawall

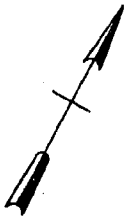


BAYSHORE



LAKESHORE

CITY OF ERIE



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1 5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

DATUM IS MEAN SEA LEVEL

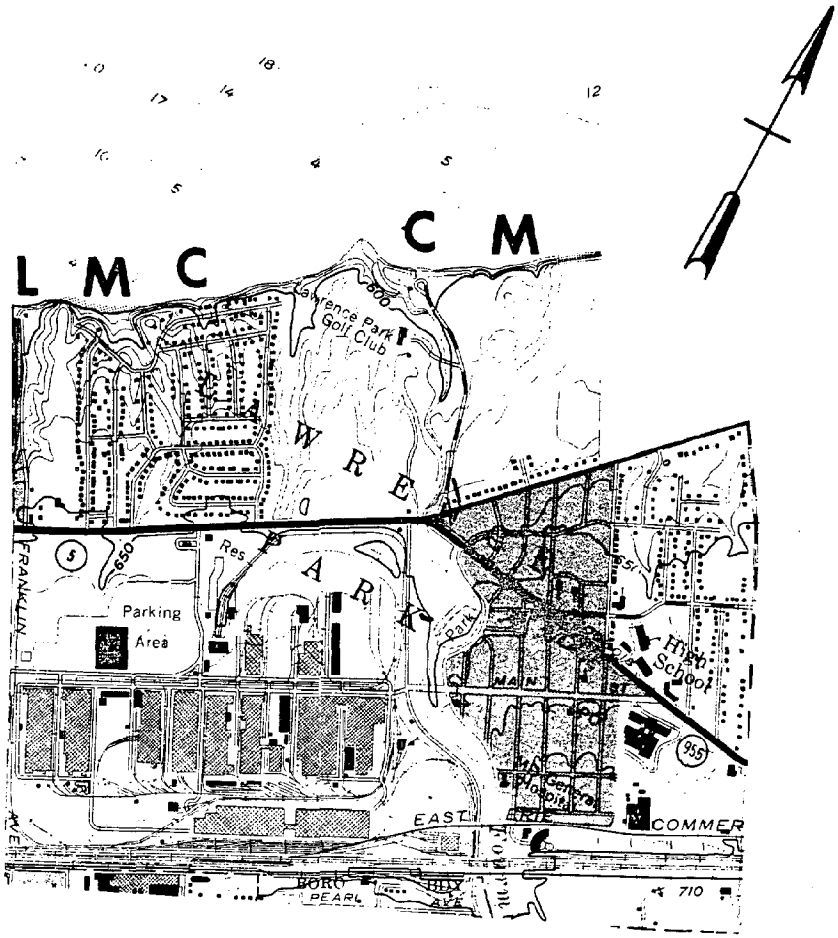
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 570.5 FEET

CITY OF ERIE, continued

HAZARD CLASSIFICATION	AREA	COMMENTS
Critical	Boathouses--Port Authority	Flooding
Limited	Lighthouse Park	Bedrock protection begins
Critical	Hammermill Paper Company	Plant at water's edge makes continued protection necessary
Moderate	Lakeside Drive Cemetery	Bedrock protection, but subject to wave uprush
Moderate	Lakeside Drive	Bedrock protection, but subject to wave uprush
Critical	Sunset Inn	Large structure on crest of bluff

LAWRENCE PARK TOWNSHIP

HAZARD CLASSIFICATION	AREA	COMMENTS
Limited	Eastminster United Presbyterian Church	Structure not in shore zone
Moderate	Lawrence Park Boat Dock	
Critical	Lakeside Drive	Low bluff subject
Critical	Lawrence Park/General Electric Fishing Club	Large boathouse at shoreline
Moderate	Lawrence Park Golf Club	



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1 KILOMETER

CONTOUR INTERVAL 10 FEET

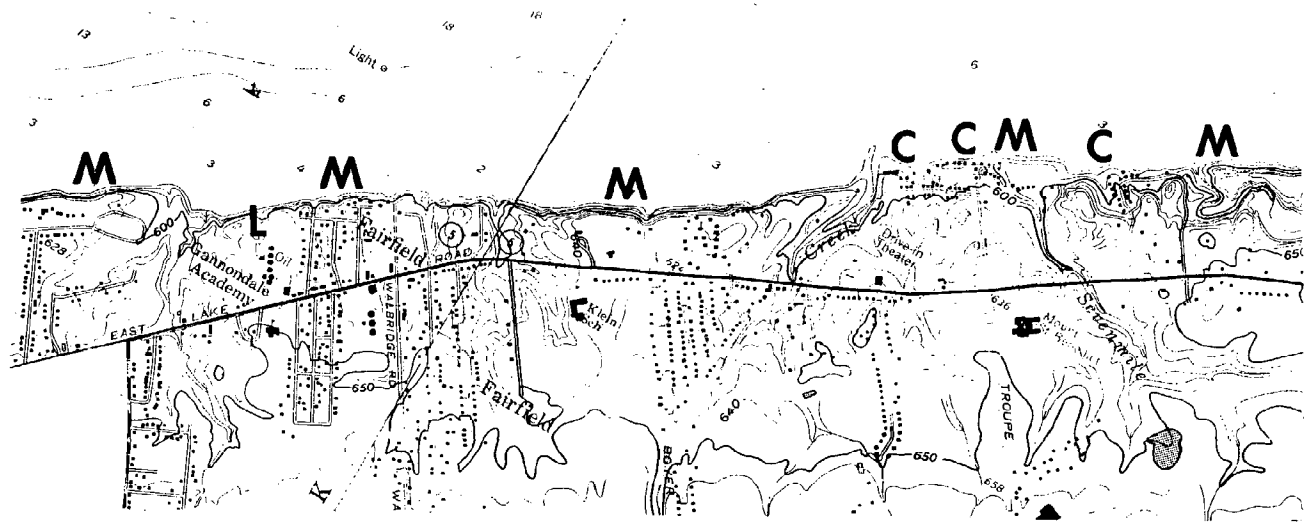
DATUM IS MEAN SEA LEVEL

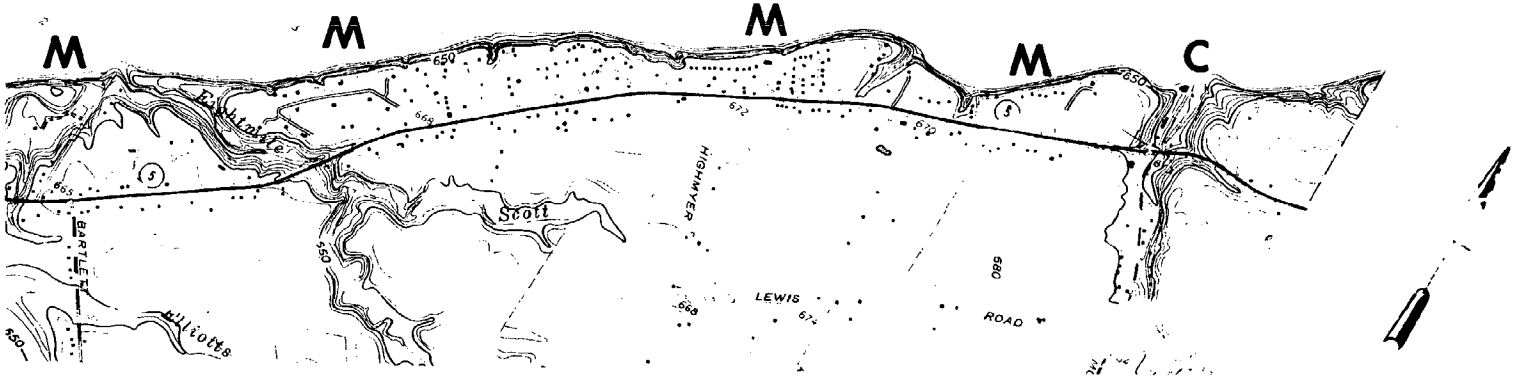
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 570.5 FEET

LAWRENCE PARK TWP.

HARBORCREEK TOWNSHIP

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Gunnison Park	Bedrock protection
Moderate	South Shore Estates	Bedrock protection
Limited	Mobil Oil Tanks	Tanks not in shore zone
Moderate	Fairfield	Bedrock protection
Limited	Faith Evangelical Lutheran Church	Structure well back from crest
Moderate	Conrad House	High rise apartment for elderly near bluff crest engineered for structural safety, but bears watching
Moderate	Cambridge Road – North-view Drive	
Critical	Cowell's Beach – Six Mile Creek	Cottages near lip of low bluff
Critical	Carter's Beach – Seven Mile Creek	Cottages near lip of low bluff
Moderate	Camp Glinodo	
Critical	Kraus Drive	Cottage near lip of low bluff
Moderate	Kraus Drive to Eight Mile Creek	
Moderate	Shades Beach County Park – Eight Mile Creek	Protected by groin





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1 KILOMETER

CONTOUR INTERVAL 10 FEET

DATUM IS MEAN SEA LEVEL

HARBORCREEK TWP.

HARBORCREEK TOWNSHIP, continued

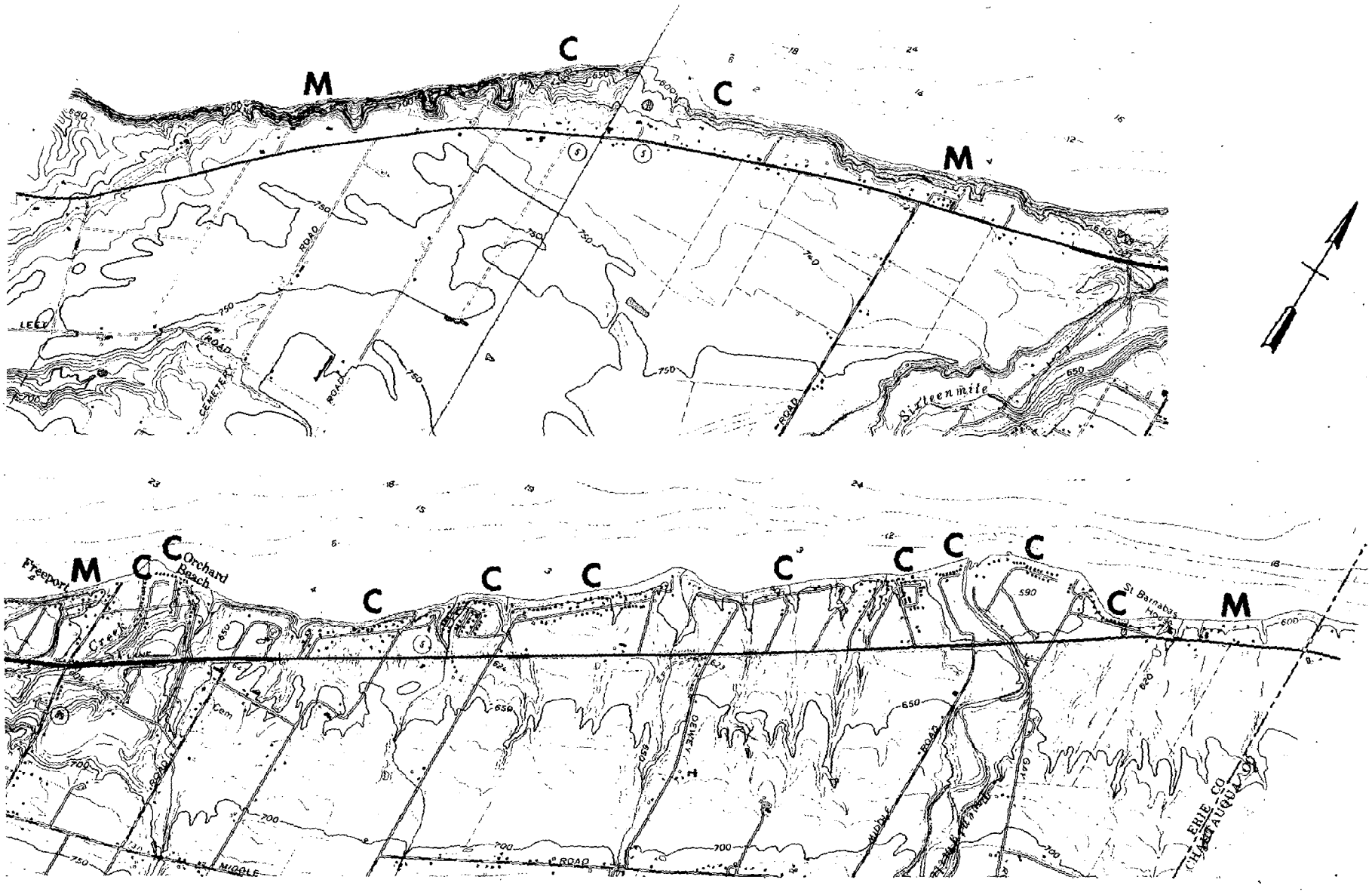
HAZARD CLASSIFICATION	AREA	COMMENTS
Limited	Lakeside Motel	Structures well back fr bluff crest
Limited	Ravine Motel	Structures well back fr bluff crest
Moderate	Lake Shore Terrace	Beach loss; toe erosion
Moderate	Indian Drive - East Drive	Beach loss; toe erosion
Moderate	Driftwood Drive	Beach loss; toe erosion
Moderate	Windsor Beach Court	Beach loss; toe erosion
Moderate	Highmyer Road to Moor-headville Road	Beach loss; toe erosion
Limited	Lakeview on the Lake Motel	Structures not on crest
Critical	Shorewood Inn/Cottages - Twelve Mile Creek	Significant beach loss, structures on beach ber subject to flooding and wave damage

NORTH EAST TOWNSHIP

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Moorheadville Road to Brickyard Road	
Critical	Brickyard Road	Two structures on edge bluff, rapid recession
Moderate	Brickyard Road to Freeport Lane	

NORTH EAST TOWNSHIP, continued

HAZARD CLASSIFICATION	AREA	COMMENTS
Moderate	Freeport Lane Freeport Yacht Club	Beach provides protection
Moderate	North East Township Beach - Freeport Road	
Critical	Sunset Beach - Sixteen Mile Creek	Subject to flooding behind a bay mouth bar
Critical	Orchard Beach	Cottages on beach berm subject to wave attack
Critical	Hutchinson's Boat Livery - Orchard Beach	Steel drum seawall provides protection
Critical	Francroft Subdivision	Heavy damage to boat houses and beach cottages
Critical	Woodmere	Same as above
Critical	Peck's Subdivision	Low bluff
Critical	Dewey Road Access Area - Pennsylvania Fish Commission	Disruption of boat access
Critical	Hidden Lane	Low bluff
Critical	Cottages - Twenty Mile Creek	Subject to flooding behind shore zone
Critical	Gay Road	Beach loss leaving structures unprotected
Moderate	St. Barnabas House	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SECTION 7
CONCLUSIONS AND RECOMMENDATIONS

STUDY CONCLUSIONS

The conclusions made as a result of the investigations conducted by GLRI include the summarization and synthesis of the interaction between natural processes and human activity. The coastal zone of Erie County is a fragile feature easily comparable to the flood plains of major streams. Just as man has competed with nature for occupance of river valleys, so too has man sought to reap the benefits provided by the shore zone. Apparent in both forms of occupance is the risk-taking by individuals gambling that the natural system will not reclaim those lands subject to continual change. Unfortunately, nature, in variance with the norm over the past five years, has built a set of conditions that has produced severe damage to the coastal zone and man's occupance of it.

The following are conclusions we have drawn combining cause and effect relationships:

1. A majority of the construction built or zoned for was done with the assumption that average water levels on Lake Erie were a constant to be depended on for planning purposes.

2. Construction in the coastal zone was done without a knowledge of the potential effects such construction would have on the stability of the bluff or the shore zone.

3. Despite periodic warnings in the form of past damages, local planning agencies have not forced a reevaluation of zoning requirements in the coastal zone.

4. Recession as a physical force is not clearly understood, with the expected misunderstanding of the often insiduous nature of this phenomena. Recession is variable with the processes that cause it and the conditions resulting. Measurement has shown those areas protected by natural or man-made features will experience less recession than an unprotected bluff. Recession will vary between a few inches to several feet annually.

5. In the past three years, the physical processes have been operating at a higher than normal rate and have resulted in disruptions, damage, and destruction. It can not be stated with any certainty whether this accelerated activity will continue and, if so, for how long.

6. We have concluded that, while floodable lands make up a small percentage of the total coastal area, persistant use of these areas for construction purposes has caused the greatest amount of damage to be focused in these areas. Rapid bluff recession is occurring primarily in areas of low density use and the damage is related to loss of land with only occasional instances of structural loss. As recession continues, however, more and more structures will be susceptible to damage.

7. The placement of groins by individuals has generally resulted in protection of the individual owner's property but is creating significant problems in the longshore transport system.

8. The value of vegetation, particularly large trees, as a means of protection is not understood by all property owners. As a result, many trees are being cut to facilitate construction or to provide a view of the lake, thus adversely affecting bluff conditions.

9. The overall disruption and localization of drainage due to man's use of the bluff is having serious effects on the bluff.

10. There is an implied monetary and benefit loss to the community in terms of a loss of tax base as real estate is lost to the lake. Also, the recreation potential of the coastal zone for local use and tourist appeal is declining as beach areas and access areas are being destroyed.

RECOMMENDATIONS

Clearly, this report is an inventory of processes and damage in the Erie County Coastal Zone, and represents a critical first step in analyzing a severe problem. As investigation was carried out over the past several months, it became increasingly apparent that a great amount of in-depth research needs to be done to fully assess the complicated coastal zone. The elements involved include the following as a means of developing an environmental assessment:

1. In order to define future recession phenomena accurately, precise measurements of bluff material must be undertaken. Sedimentary analysis, section measurement, and movement due to shear failure in these materials are expected elements.

2. A complete study of types and extent of slope failure due to slumping, debris slides and falls will reveal areas of special concern and substantiate evidence gathered during recent investigations.

3. A ground water analysis should be undertaken in the bluff zone since it is apparent that, as a contributory factor in recession, it is as important as wave undercutting.

4. A monitoring of GLRI control points over the next year will help to substantiate data collected by photogrammetric means.

5. On-site monitoring of storms in selected areas sensitive to wave attack should be conducted to determine the effects of short term erosion phenomena.

6. A sediment loading study should be made to determine quantities of materials removed. This is especially important as a correlative factor in the effects produced by dredging in the near-shore for sand materials.

7. An in-depth examination of the dredging problem and the effect on bluff recession.

8. A complete examination of storm damage to land in all categories of use over a long term.

Each of the above will allow the planner to restrict future development to areas presenting the least threat to environmental conditions and to individuals seeking to gain the advantages provided by the coastal zone interface.

APPENDIX A

NATIONAL SHORELINE STUDY

ERIE COUNTY SHORELINE

Section 9
COMMONWEALTH OF PENNSYLVANIA

The Great Lakes Shoreline in Pennsylvania is located in the Lake Erie East Planning subarea 4.4 (Figure 63). The shoreline is 48.3 miles long and consists of high erodible bluffs fronted by sand and gravel beaches. Presque Isle Peninsula which encloses Erie Harbor is a large sand spit developed as a park by the State of Pennsylvania. The single county area has a population of 257,000 (1970). The major urban center is Erie.

The shoreline of Pennsylvania is divided 21.2 miles residential, 3.6 miles industrial and commercial, 11.6 miles public recreation, and 11.9 miles agricultural and undeveloped. Shoreline ownership is classified 11.6 miles non-Federal public and 36.7 miles private. The entire shoreline is subject to significant erosion except where protective works have been constructed. About 36.1 miles of shoreline are subject to noncritical erosion and 5.3 miles are protected. Six miles of shore on the Presque Isle Peninsula are subject to critical erosion. A suitable method of protecting this reach is groins and artifical beach fill. The estimated cost is about $5 million dollars.

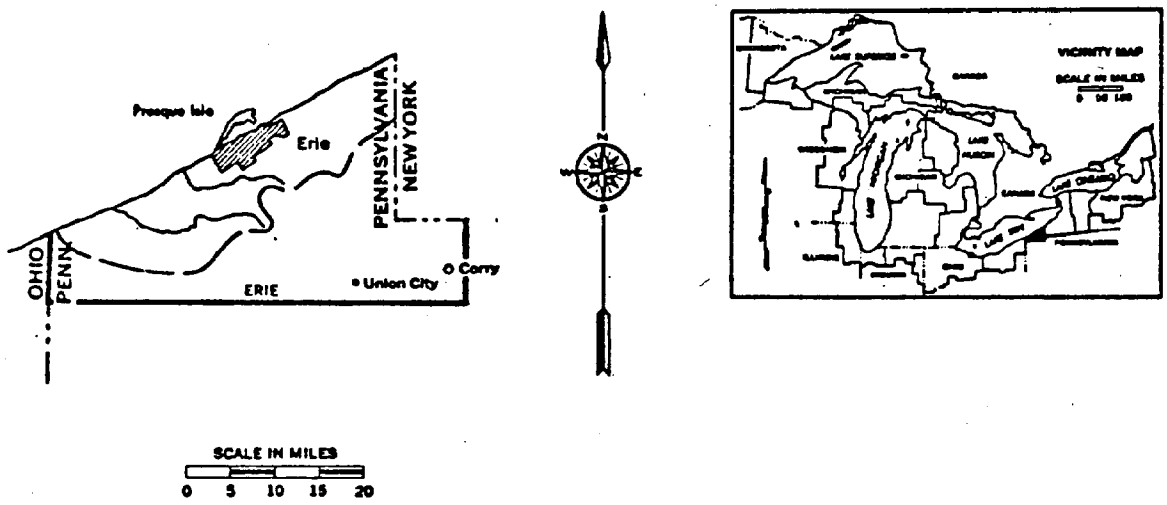


Figure 63. Lake Erie East Planning Subarea 4.4, Pennsylvania.

9.1 Shoreland Description

Erie County, Pennsylvania, which has a shore frontage of 48.3 miles, is the only Pennsylvania frontage on Lake Erie. It lies between Ashtabula County, Ohio, and Chautauqua County, New York. The shore bluffs are generally 50 feet to 75 feet high and rise to 100 feet high in a few places. Between the Ohio-Pennsylvania line and Erie, which includes the westerly half of the shore, the bluffs are entirely silt, clay, and granular material, with shale bedrock at about water level. To the east of Erie Harbor, the shale bedrock is frequently from 15 to 35 feet above the lake level, and the upper part of the bluff is composed of silt, clay, and granular material. Sand and gravel benches up to 150 feet wide extend along the toe of the bluffs. Figure 64 and Table 42 illustrate shoreline values, uses, ownership, and problem areas for this shoreline reach.

The westerly eight miles of the shore, from the Ohio-Pennsylvania line to the mouth of Elk Creek, is thinly populated. In the first two miles, where a highway closely follows the lakeshore, a single row of residences and summer homes borders the lakeshore. The next three miles are mostly occupied by organizational camps, and the two miles of shoreline west of Elk Creek are undeveloped and quite heavily wooded. Between Elk Creek and Erie Harbor, the shore development increases. Many of the shore properties in this reach are high-value permanent homes.

Table 42

Shoreline of the Great Lakes — Erie County, Pennsylvania

Shoreland Use Category	Existing Shoreland Use			Miles of Shoreline			Problem Identification Miles of Shoreline				
	Miles of Shoreline	Percent of Total	Number of Sites	Public		Private	Subject to Erosion		Protected	Subject to Flooding	Not Subject to Erosion or Flooding
				Federal	Non-Federal		Critical	Noncritical			
Economic Uses											
Residential	21.2	43.8		0	0	21.2	0	20.5	0.7	0	0
Industrial and commercial	3.6	7.4		0	0	3.6	0	3.1	0.5	0	0
Agricultural and undeveloped	11.9	24.8		0	0	11.9	0	11.9	0	0	0
Commercial harbors			1								
Electric power sites			1								
Public buildings and related lands	0	0		0	0	0	0	0	0	0	0
Recreational Uses											
Parks	11.6	24.0		0	11.6	0	6.0	0.5	5.1	0	0
Recreational boat harbors			4								
Beach zone	(48.3)	(100.0)		(0)	(11.6)	(36.7)					
Environmental Uses											
Wildlife perserves and game lands	0	0		0	0	0	0	0	0	0	0
Fish and wildlife wetlands (offshore)	(0)	0					0	0	0	0	0
Forest	0	0					0	0	0	0	0
Total	48.3	100.0		0	11.6	36.7	6.0	36.0	6.3	0	0

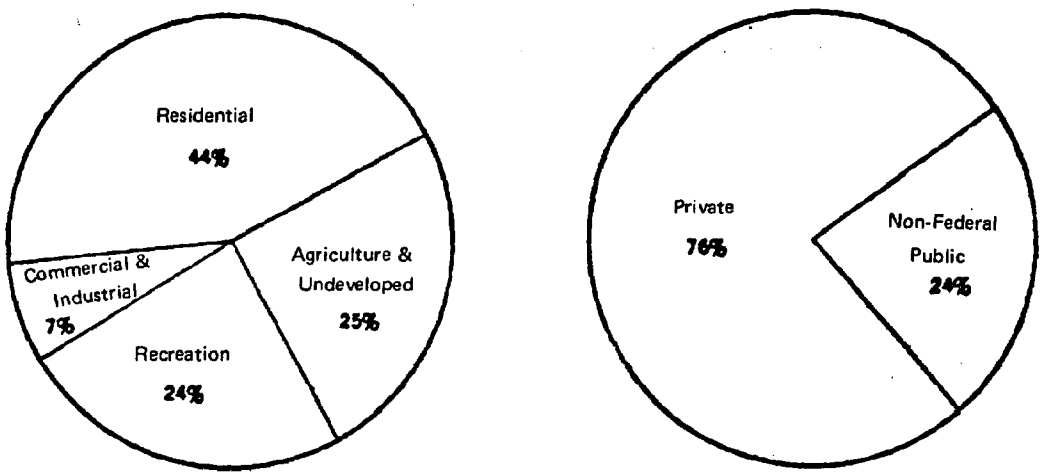


Figure 65. Distribution of Shoreline Use and Ownership, Erie County, Pennsylvania.

The first mile of shore east of Erie Harbor is occupied by a steel mill and a paper mill. The next eight miles, to the mouth of Twelve-mile Creek, are developed with residences and a golf course. The next four miles, to near Sixteen-mile Creek, is generally undeveloped. The shore from there to the Pennsylvania-New York line is being developed for residential use. The westerly half of the mainland shore in the city of Erie within Presque Isle Bay is residential. The easterly half is commercial and industrial. Presque Isle Peninsula, which encloses Erie Harbor, is a large sand spit developed as a state park. The distribution of shoreline use and ownership is shown in Figure 65.

Presque Isle State Park has the largest and best public beach on Lake Erie. It has a total shoreline of over seven miles on its lakewood edge and almost as much on the bay side of the peninsula. Its unique formation and development are of considerable ecological and botanical interest. Perry's Monument on the peninsula is of historical interest as a memorial to Commodore Perry, whose fleet defeated the British in Put-in-Bay in 1813.

In addition to this 3,200-acre park, the Commonwealth owns lake frontage at the mouth of Walnut Creek and at the Borough of Northeast, about two miles west of the New York State line. These areas are managed by the Pennsylvania Fish Commission. There is a local community park in the Borough of Lake City located near the mouth of Elk Creek. For its future recreational needs, Erie County has proposed six new lake front park developments. These would be located at the mouths of the following tributary streams: Racoon Creek, Crooked Creek, Elk Creek, Eight-Mile Creek, Sixteen-Mile Creek, and Twenty-Mile Creek. In addition, Erie County would like to preserve the tributary valleys as natural areas for hiking trails and fishing.

There is a Federal deep-draft navigation project at Erie Harbor. A Federal small-boat harbor has been authorized at Elk Creek, where there are private marina facilities. And a study is underway for a new Federal small-boat harbor at Northeast, Pennsylvania, about two miles from the Pennsylvania-New York line. The Commonwealth is planning further improvement at the mouth of Walnut Creek to accomodate small boats now using its public launching ramp. There is a large marina operated by the Commonwealth in Presque Isle State Park. There are also private marina facilities and a yacht club in Presque Isle Bay.

97-908 O-73-vol. V-11

Table 43
Total Damage to Shore Property on Lake Erie — Erie County, Pennsylvania

Land Use	Damages, $	
	Actual 1951-52 Value	Updated 1970 Value
Private		
Residential	400	800
Industrial and commercial	1,800	3,500
Agricultural and undeveloped	4,300	4,500
Total, private property	6,500	8,800
Public		
Parks and beaches	442,000	1,021,000
Total, public property	442,000	1,021,000
Total erosion damages	448,500	1,029,800

9.2 Erosion and Flooding History

Erosion of the bluffs is generally noncritical, since sand and gravel beaches provide good protection. Beaches in some of the highly developed residential and camp areas between the Ohio-Pennsylvania line and Erie have been improved by construction of groins. Erosion of the frontage east of Erie Harbor is further slowed by the shale in the lower part of the bluffs. In general, the development is well back from the bluff face and, except in a few isolated cases there has been no critical erosion damage, apart from the lakeward edge of Presque Isle Peninsula.

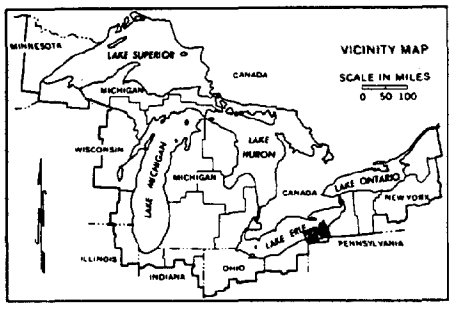
Erosion damages reported in the damage survey made in 1951-52 in Erie County are shown in Table 43. The principal damages shown occurred at Presque Isle State Park.

Presque Isle Peninsula has a history of serious and continuous erosion. It consists entirely of fine sand, with a surface elevation averaging about seven feet above low water datum. Parts of the peninsula are low marshes, which are flooded during extreme high lake stages. Its principal problem, however, is erosion of its lakeward edge. Due to littoral forces, the peninsula tends to move in an easterly direction, and several wide breaks have occurred in the narrow neck in the past 150 years. Between 1872 and the present time, much of the peninsula has been progressively protected by groins, bulkheads, and sand fill. This work has been done by the city of Erie, the Commonwealth, and the Federal Government. The latest Federal project, in cooperation with the Commonwealth, provided for construction of groins along the neck of the peninsula and placement and replenishment of sand fill where needed along the entire lakeward edge.

9.3 Solutions to Erosion Damages

The cooperative beach erosion project at Presque Isle was authorized as recommended in a report of the Chief of Engineers in October 1952, published in House Document No. 231, 83rd Congress, 1st Session. A later report, published in House Document No. 397, 86th Congress, 2nd Session, recommended Federal help in beach replenishment for the original project, in which about 4,200,000 cubic yards of sand fill were placed and 11 groins were constructed. Replenishment requirements have been greater than originally estimated, and a review study is now underway to find means of reducing those requirements. The rate of natural accretion is obviously not enough to maintain the extensive park beaches. Costs of the cooperative project to date have been a little over $4 million. An additional $2 million to $5 million may be required for additional groins or other project changes and replenishment of the beach fill, to restore the project. The rate of littoral drift, particulary west of Presque Isle, is sufficient that groins have successfully protected long lengths of privately owned shore.

Other than further participation in the Presque Isle project, there are no other critical erosion or flooding problems along the Lake Erie shore of Pennsylvania of interest to the Federal Government at this time.

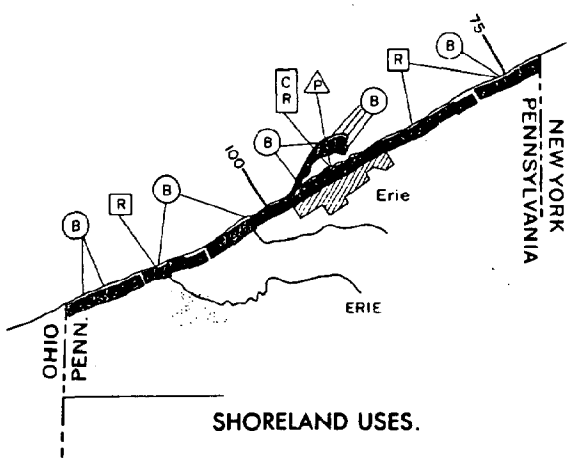


SEE REVERSE PAGE FOR LEGEND

SCALE IN MILES

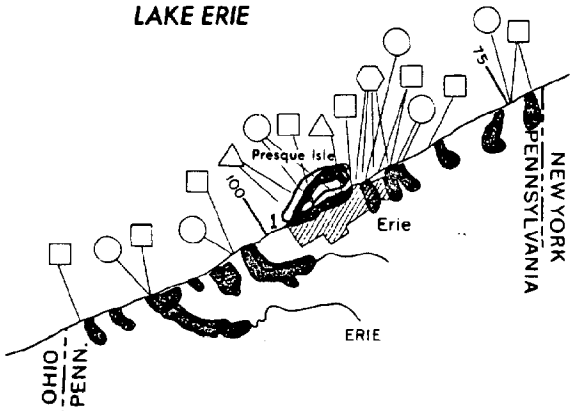
0 5 10 15

LAKE ERIE



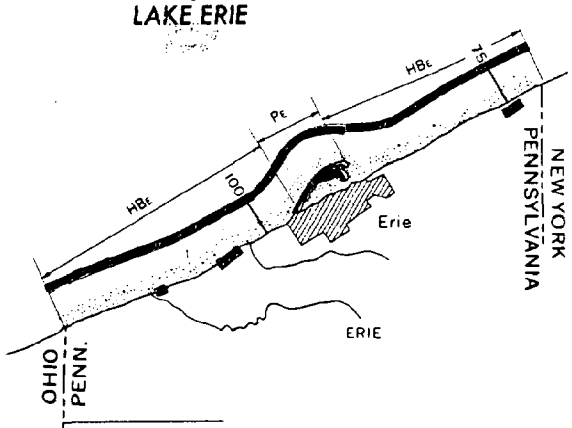
SHORELAND USES.

LAKE ERIE



ENVIRONMENTAL VALUES, WATER INTAKES AND WASTE OUTFALLS.

LAKE ERIE



PHYSICAL DESCRIPTION, OWNERSHIP, AND EROSION AND FLOODING PROBLEM REACHES.

SHORELANDS OF THE GREAT LAKES, ERIE COUNTY

LEGEND

SHORELAND USES

Commercial, Industrial, Residential and Public Buildings

Recreational and Urban Open Space

Agricultural and Undeveloped

Forest

Public Beaches — B

Commercial Deep Draft Harbors — C

Recreational Harbors — R

Commercial Deep Draft and Recreational Harbors — C R

Electric Power Stations — P

ENVIRONMENTAL VALUES, WATER INTAKES AND WASTE OUTFALLS

Significant Fish and Wildlife Values

Unique Ecological or Natural Areas

Outstanding Shoreland Areas of Possible National Interest

Potential Recreation Sites

Waste Water Outfalls and Intakes

Public Outfalls

Public Intakes

Private Outfalls

Private Intakes

Critical Bird Nesting and Migration Areas — 2

PHYSICAL DESCRIPTION, OWNERSHIP, AND EROSION AND FLOODING PROBLEM REACHES

Federal Lands

Non-Federal Public Lands

Private Lands

Shore type

Artificial Fill Area — A

Erodible High Bluff, 30 ft. or higher — HB_E

Non-Erodible High Bluff, 30 ft. or higher — HB_N

Erodible Low Bluff, less than 30 ft. high — LB_E

Non-Erodible Low Bluff, less than 30 ft. high — LB_N

High Sand Dune, 30 ft. or higher — HD

Low Sand Dune, less than 30 ft. high — LD

Erodible Low Plain — P_E

Non-Erodible Low Plain — P_N

Wetlands — W

Combinations Shown As: Example

Lakeward/Landward — W/P_E

Upper Bluff Material / Lower Bluff Material — $\frac{HB_E}{HB_N}$

Beach Material

Sand and gravel

Ledge rock

No Beach

Problem Identification

Areas subject to erosion generally protected

Critical erosion areas not protected

Non-critical erosion areas not protected

Shoreline subject to lake flooding

Shoreline not subject to erosion or flooding

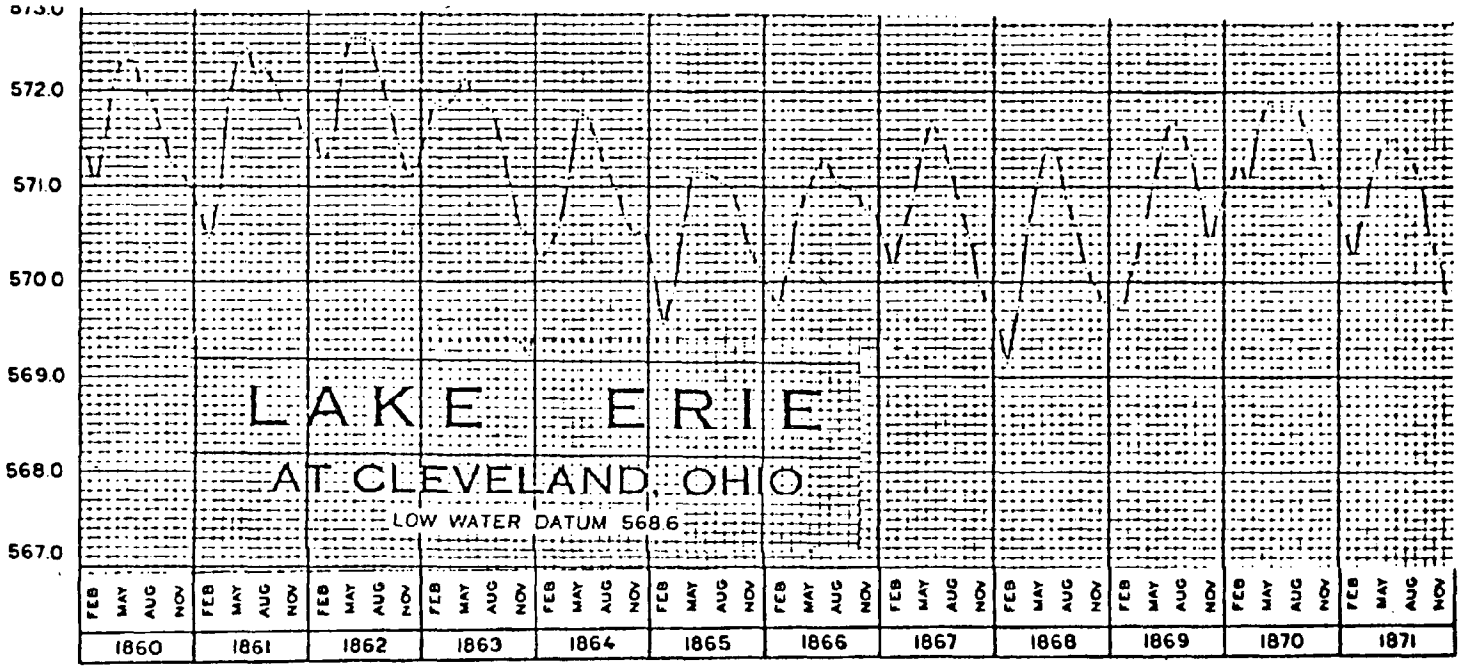
Bluff seepage problems — S

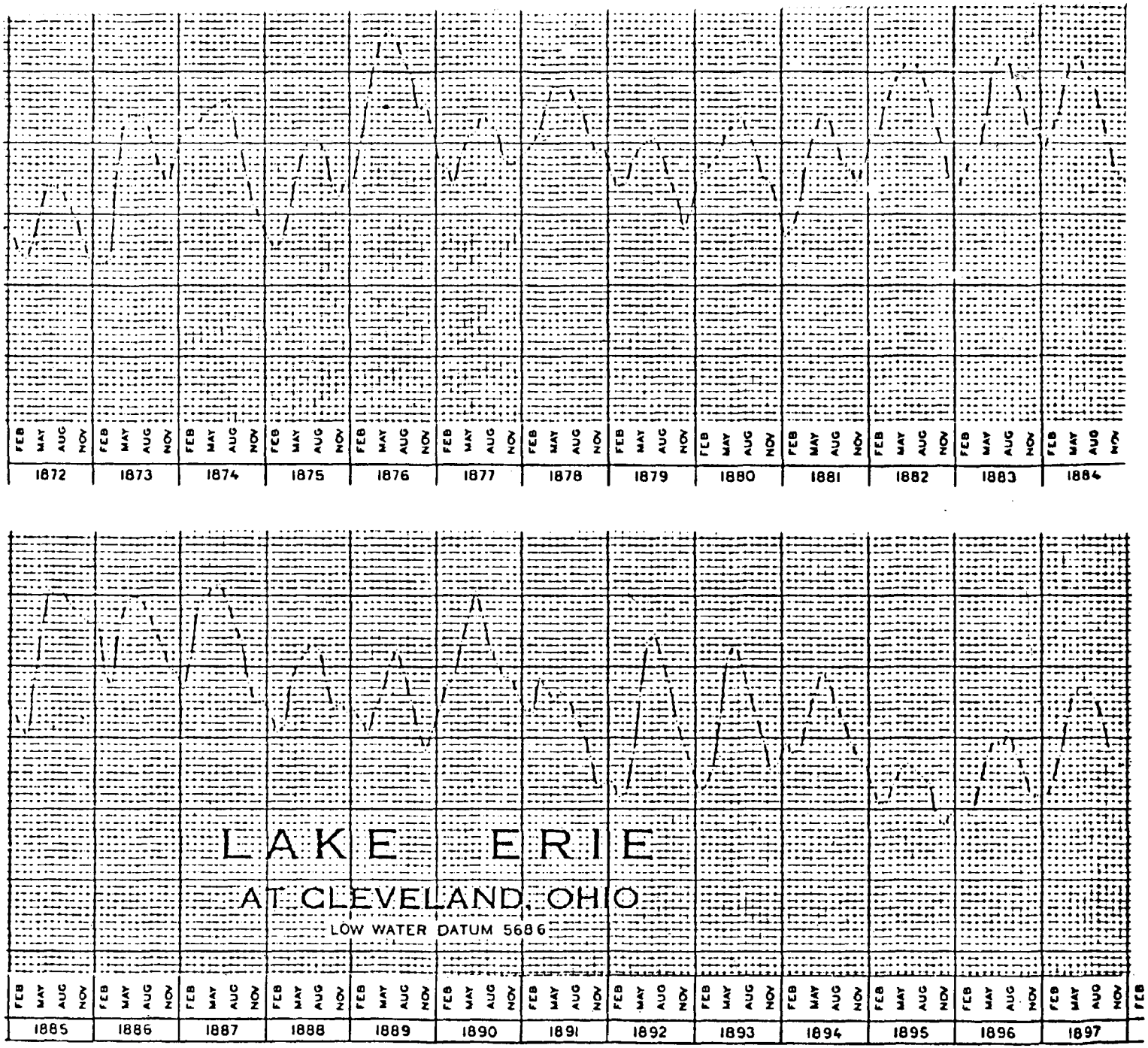
APPENDIX B
WATER LEVELS HYDROGRAPH
1860–1975

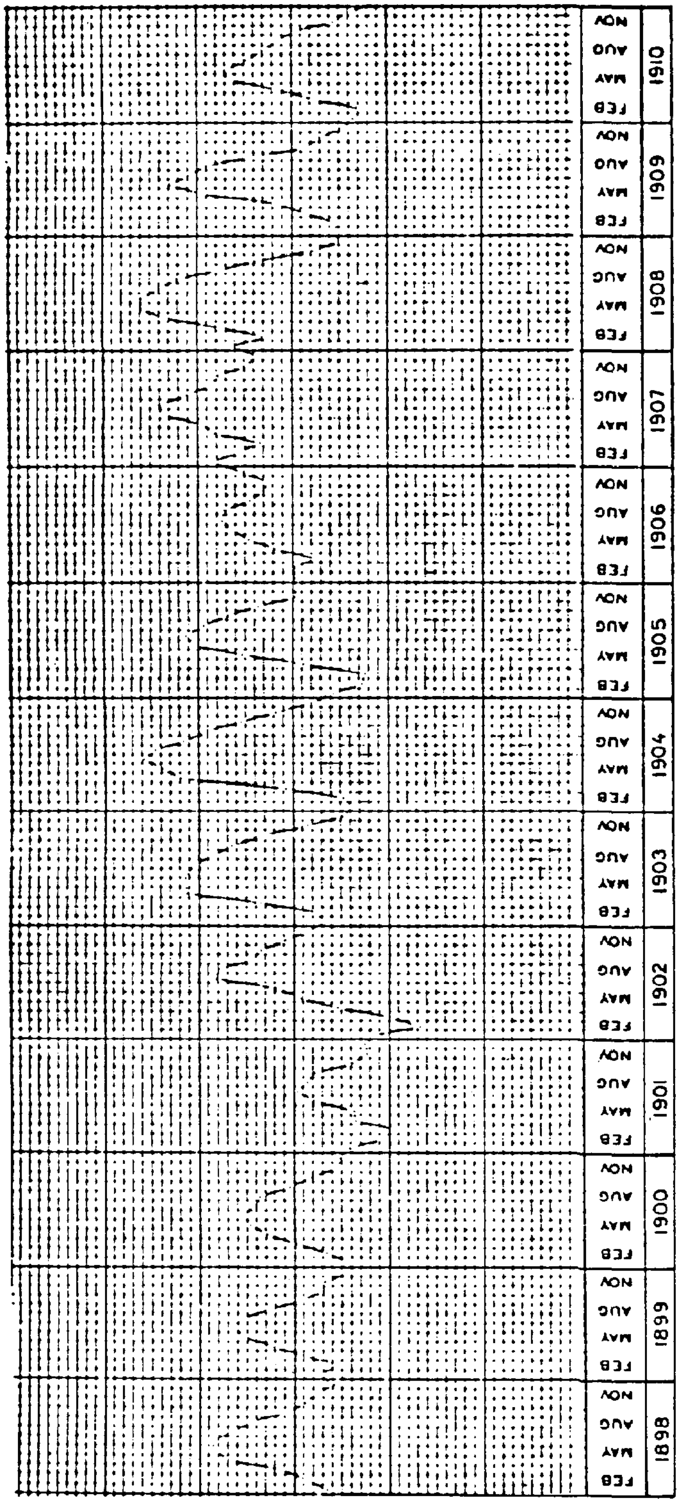
LAKE SURVEY CENTER, NOAA – U. S. DEPARTMENT OF COMMERCE

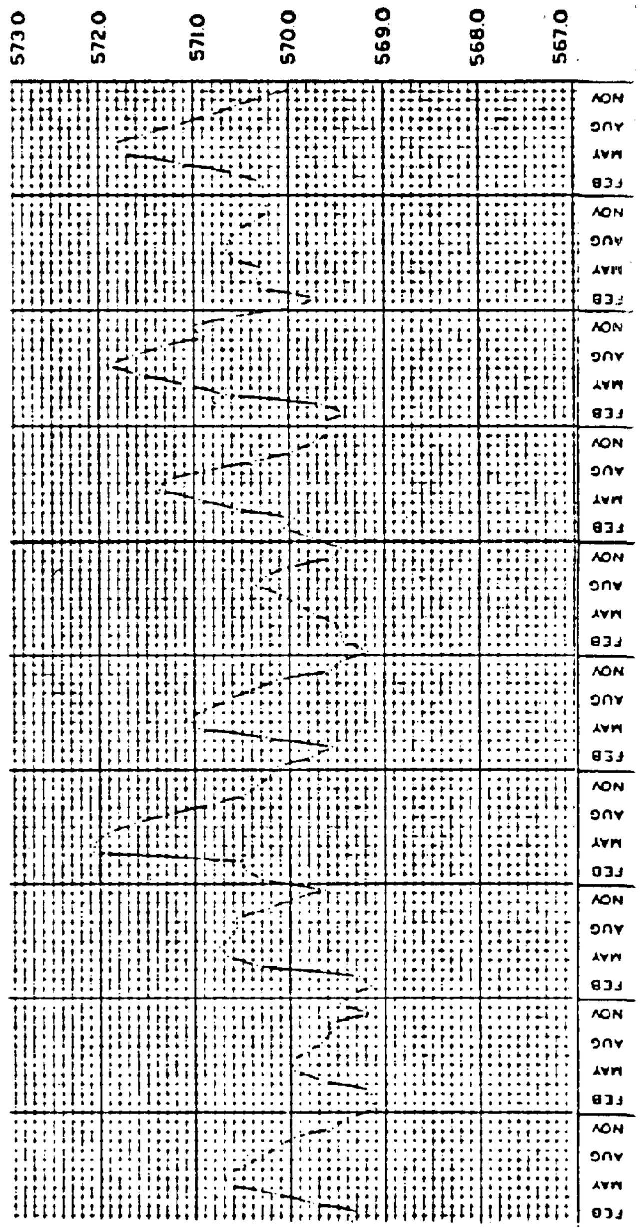
HYDROGRAPH OF MONTHLY MEAN LEVELS OF THE GREAT LAKES

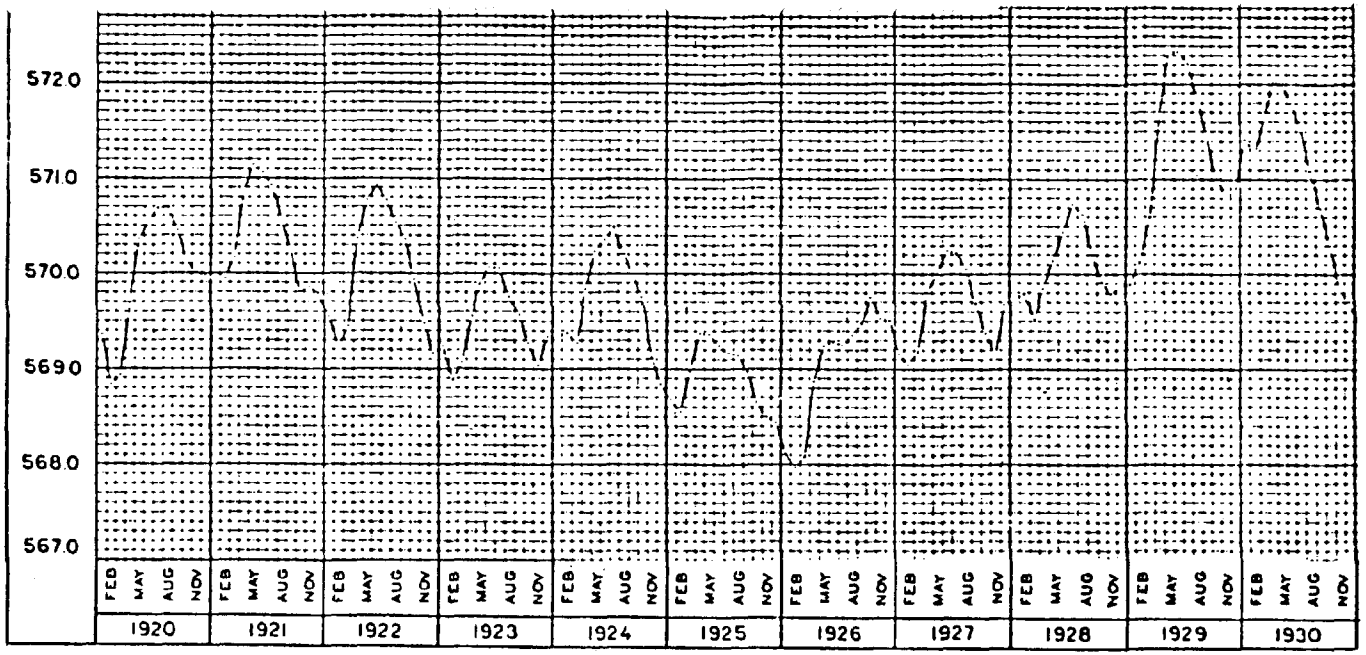
ELEVATIONS IN FEET ABOVE MEAN WATER LEVEL AT FATHER POINT, QUEBEC INTERNATIONAL GREAT LAKES DATUM (1955)




FEB MAY AUG NOV
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
LAKE ERIE
AT CLEVELAND, OHIO
LOW WATER DATUM 568.6
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897


1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
FEB
MAY
AUG
NOV


573.0
572.0
571.0
570.0
569.0
568.0
567.0
FEB
MAY
AUG
NOV


572.0
571.0
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569.0
568.0
567.0
FEB MAY AUG NOV
1920
1921
1922
1923
1924
1925
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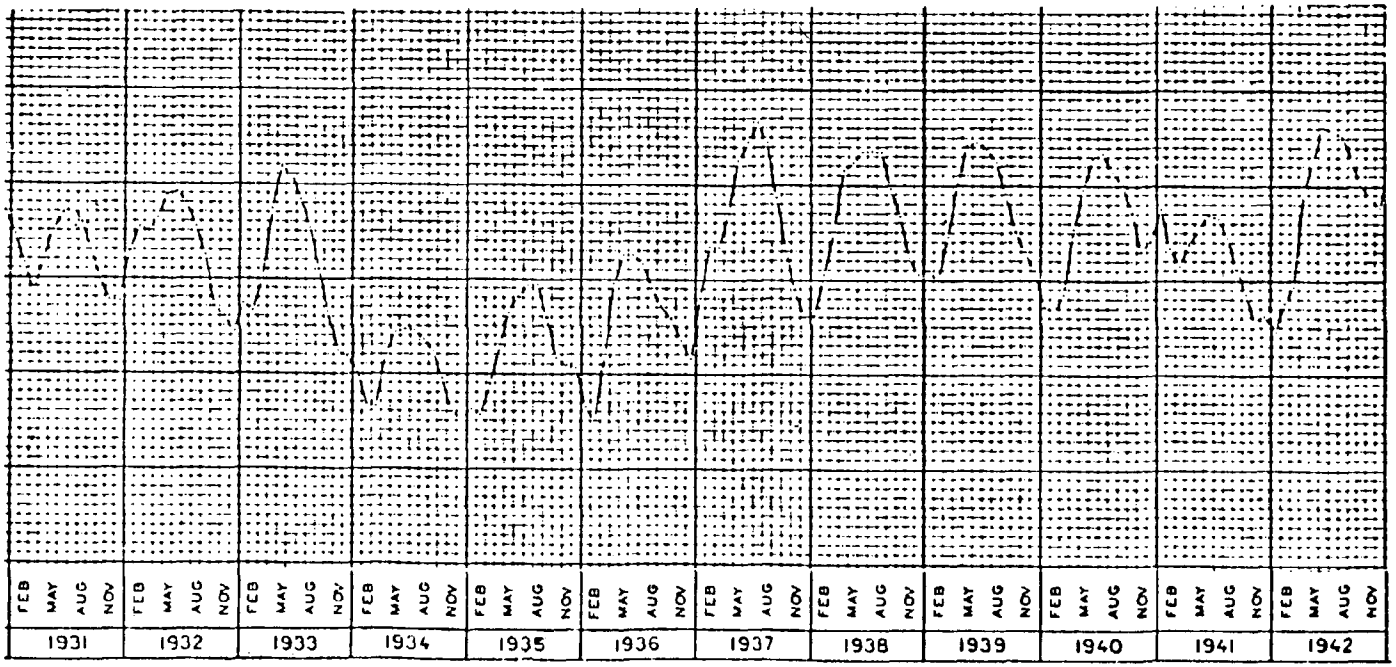
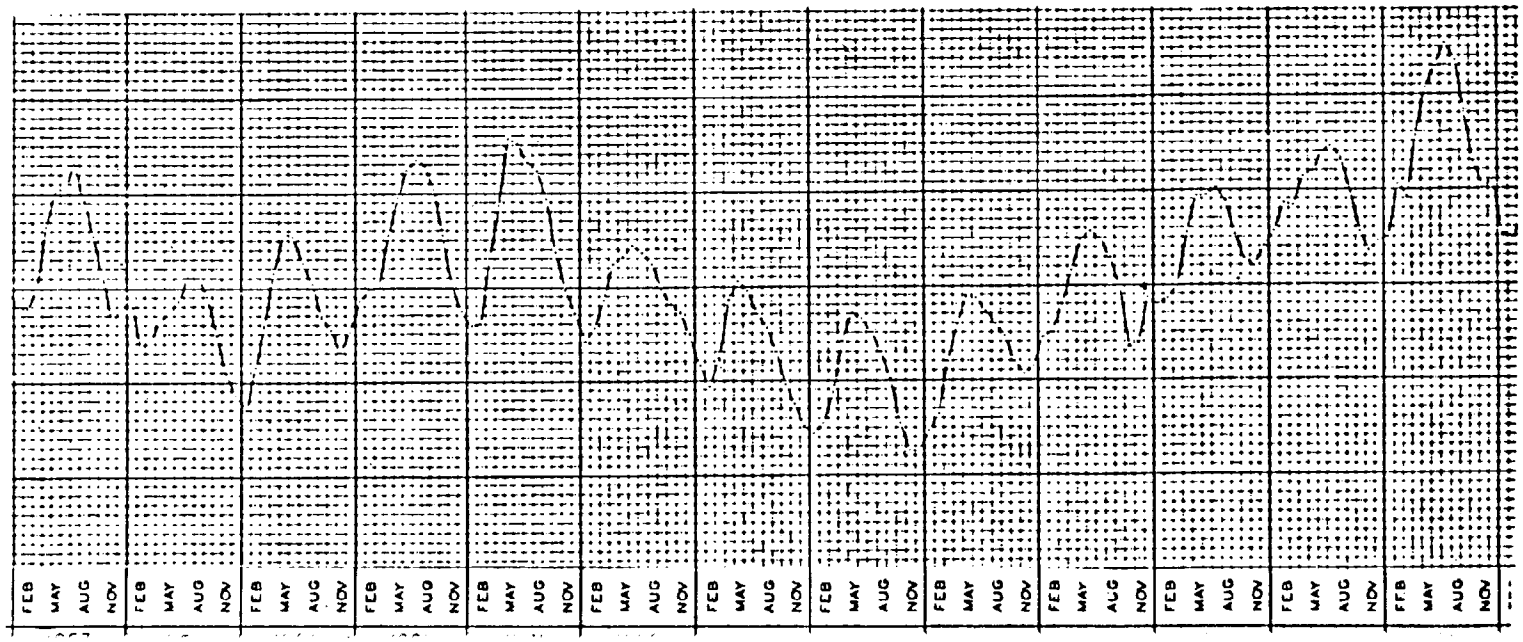
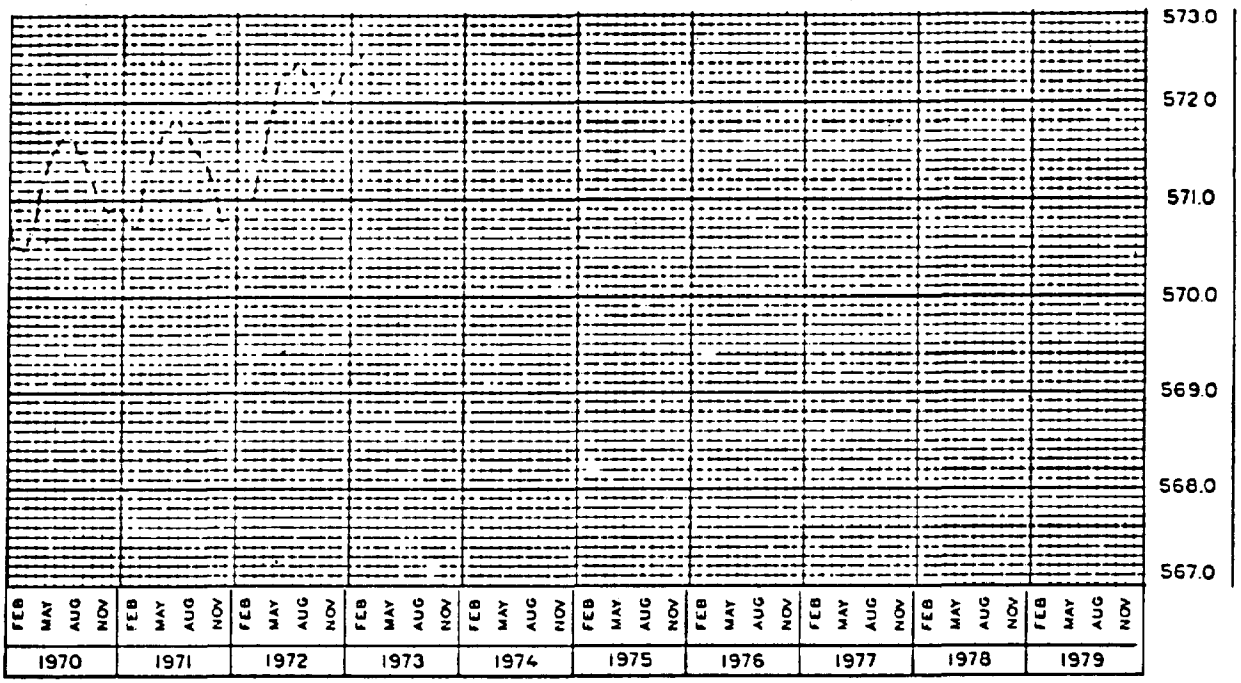
1927
1928
1929
1930

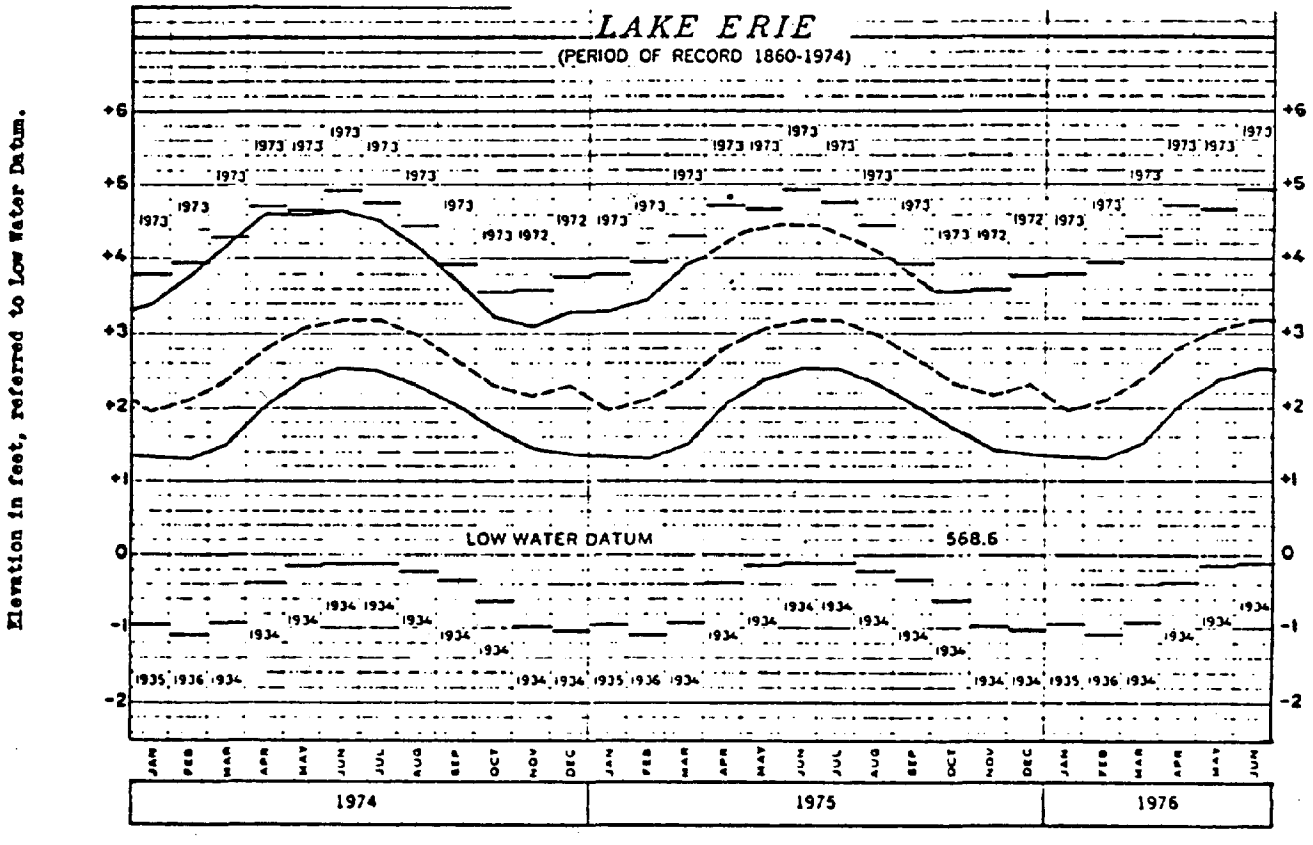

FEB MAY AUG NOV
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942


LAKE ERIE
AT CLEVELAND, OHIO
LOW WATER DATUM 568.6
FEB MAY AUG NOV
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956


FEB MAY AUG NOV



MONTHLY BULLETIN OF LAKE LEVELS FOR MARCH 1975



APPENDIX C
COMPUTER CALCULATION
OF RECESSION RATES

EDINBORO STATE COLLEGE
COMPUTER CENTER

PROGRAM SUMMARY SHEET

PROGRAM NAME	SCALCO
WRITTEN BY	Marc Solomom
PROGRAM LANGUAGE	FORTRAN-IV
DATE WRITTEN	April, 1975
CORE REQUIRED	48120 bytes
CONFIGURATION REQUIREMENTS	1 reader, 1 printer

PROGRAM FUNCTION This program was designed to input for three years, various reference line measurements and reference point measurements. Using the reference point measurements, a scale is computed for each year. Having this value, all map inches are converted to actual inches. The program ultimately shows the advance or withdrawal of a bluffline to a reference line. Using the average distance for years 1 and 3, the program predicts where the shoreline is in the year 2000. If you wish to change the year 2000 to some other date, then lines 78 and 83 of the program would have the number 100 changed, e.g., if you want 2050, then change the 100 to 150 in 78 and 83. Also, lines 70 and 85 must have the literal changed.

```
      DIST(2,I)=DIST(2,1)-DIST(3,I)
14    DIST(3,I)=DDIST(I)-DIST(3,I)
      WRITE(6,15)NYEAR(1),NYEAR(2),(DIST(1,J),J=1,N)
      WRITE(6,15)NYEAR(2),NYEAR(3),(DIST(2,J),J=1,N)
      WRITE(6,15)NYEAR(1),NYEAR(3),(DIST(3,J),J=1,N)
15    FORMAT(3X,12,' - ',12,2X,10(F8.1,1X))
COMPUTE AVERAGE DISTANCE = DISTANCE DIFFERENCE / (NO. OF YEARS)
      DO 16 I=1,N
      DIST(1,I)=DIST(1,I)/(NYEAR(2)-NYEAR(1))
      DIST(2,I)=DIST(2,I)/(NYEAR(3)-NYEAR(2))
16    DIST(3,I)=DIST(3,I)/(NYEAR(3)-NYEAR(1))
      WRITE(6,17)
17    FORMAT('0',25X,'AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)'
     -/'  FOR YEAR'/)
      WRITE(6,32)(J,J=1,N)
      WRITE(6,15)NYEAR(1),NYEAR(2),(DIST(1,J),J=1,N)
      WRITE(6,15)NYEAR(2),NYEAR(3),(DIST(2,J),J=1,N)
      WRITE(6,15)NYEAR(1),NYEAR(3),(DIST(3,J),J=1,N)
      WRITE(6,18)
18    FORMAT('0DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
     -'/' BASED ON AVERAGE OF FIRST AND LAST YEARS'/)
       WRITE(6,33)(J,J=1,N)
33    FORMAT(' ',3X,10(I2,8X))
COMPUTE DISTANCE FROM REFERENCE LINE IN THE YEAR 2000
C  DISTANCE = YEAR 1 DISTANCE - AVERAGE DISTANCE DIFFERENCE FOR
C   YEARS ONE AND THREE * (100 - YEAR(1))
      DO 19 I=1,N
19    DIST(2,I)=DDIST(I)-DIST(3,I) *(100-NYEAR(1))
      WRITE(6,20)(DIST(2,J),J=1,N)
20    FORMAT(10F10.1)
COMPUTE DISTANCE DIFFERENCE BETWEEN YEAR THREE AND 2000
      DO 35 I=1,N
35    DIST(2,I)=DIST(3,I)*(100-NYEAR(3))
      WRITE(6,34)
34    FORMAT('0',25X,'DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEA
     -R (ACTUAL INCHES)'/)
      WRITE(6,33)(J,J=1,N)
      WRITE(6,20)(DIST(2,I),I=1,n)
      GO TO 100
1000  STOP
      END
```

FORTRAN IV (VER L43) SOURCE LISTING: 04/08/75

```
 1         PROGRAM SCALCO
 2         DIMENSION TITLE (20), A(3), Y(3), NYEAR(3), DIST(3,10)
 3        -,SCALE(3),DDIST(10)
 4 C  INPUT HEADING CARD
 5 100     READ(5,1,END=1000)TITLE
 6 1       FORMAT(20A4)
 7         DO 2 I=1,3
 8 C  INPUT SET OF THREE CARDS WITH LESSER VALUE YEAR FIRST
 9 C    NTEAR(1)  =  1 TH YEAR
10 C    A(1)      =  REFERENCE DISTANCE TAKEN FROM PHOTO
11 C    Y(I)      =  REFERENCE DISTANCE TAKEN FROM TOPO MAP
12 C    N         = NUMBER OF DATA POINTS
13 C    DIST(I,J) =  DISTANCE ON PHOTO FROM REFERENCE LINE FOR I TH
14 C                 YEAR AND J TH DATA VALUE
15        READ(5,4)NYEAR(I),A(I),Y(I),N,(DIST(I,J),J=1,N)
16 4      FORMAT(I2,1X,F6,3,1X,F6.3,1X,I2,1X,10F6,3)
17 COMPUTE SCALE FOR EACH YEAR
18 2      SCALE(I)=(Y(I)*24000.)?A(1)
19        WRITE(6,5)TITLE
20 5      FORMAT('1',20X,20A4)
21        WRITE(6,6)
22 6      FORMAT('0',25X,'DISTANCE FROM REFERENCE LINE (MAP INCHES)'
23       -/' FOR YEAR'/)
24        WRITE(6,30)(J,J=1,N)
25 30     FORMAT(' ',19X,10( 12,6X))
26        DO 7 I=1,3
27 7      WRITE(6,8)NYEAR(I),(DIST(I,J),J=1,N)
28 8      FORMAT(4X,I2,12X,10(F6.3,2X ))
29        WRITE(6,10)
30 10     FORMAT('0',25X,'DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)'
31       -/'  FOR YEAR',3X,'SCALE'/)
32        WRITE(6,31)(J,J=1,N)
33 31     FORMAT(' ',19X,10(6X,I2,3X))
34 COMPUTE ACTUAL DISTANCE = MAP DISTANCE * SCALE
35        DO 28 I=1,3
36        DO 9 J=1,N
37 9      DIST(I,J)=DIST(I,J)*SCALE(I)
38 28      WRITE(6,11)NYEAR(I),SCALE(I),(DIST(I,J),J=1,N)
39 11     FORMAT(4X,I2,5X,11(F9.1,2X))
40        WRITE(6,12)
41 12     FORMAT('0',25X,'DISTANCE DIFFERENCES (ACTUAL INCHES)'
42       -/'  FOR YEAR'/)
43        WRITE(6,32)(J,J=1,N)
44 32     FORMAT(' ',15X,10(I2,7X))
45 C    SAVE ACTUAL DISTANCE FOR YEAR ONE
46        DO 13 I=1,N
47 13     DDIST(I)=DIST(1,I)
48 COMPUTE DISTANCE DIFFERENCES
49        DO 14 I=1,N
50        DIST(1,I)=DIST(1,I)-DIST(2,I)
```

EQUATIONS USED

Scale:

Scale (I) = (Y(I)*24000.)/A(I)

Distance from Reference Line (Actual Inches)

DIST(I,J) = MAP DISTANCE (I,J)*SCALE(I)

Distance Difference

DD(1) = DIST(1,I)-DIST(2,I)
DD(2) = DIST(2,I)-DIST(3,I)
DD(3) = DIST(1,I)-DIST(3,I)

Average Distance

AVDD(1) = DD(1)/(YEAR(2)-YEAR(1))
AVDD(2) = DD(2)/(YEAR(3)-YEAR(2))
AVDD(3) = DD(3)/(YEAR(3)-YEAR(1))

where, I = subscript on year, i=1,2,3
J = subscript on distance value, j=1-10
A(I) = ith map reference distance
Y(I) = ith topo reference distance
YEAR(I) = last two digits of year of consideration

LAYOUT OF INPUT DATA CARDS

The input consists of a group of four cards. The first card is the title card. The user may use all 80 columns for title purpose. Cards 2, 3, and 4 are used to input the data to be processed by the program. Each of these Cards 2, 3, and 4 have the same layout.

Column	Description
1-2	Last two digits of year of consideration.
3	Blank
4-9	Reference distance as measured from photo.
10	Blank
11-16	Reference distance as measured from topo map.
17	Blank
18-19	Number of distance values to follow (max. of 10)
20	Blank
21-26	Distance Value 1
27-32	" " 2
33-38	" " 3
39-44	" " 4
45-50	" " 5
51-56	" " 6
57-62	" " 7
63-68	" " 8
69-74	" " 9
75-80	" " 10

The year of lowest value is first, followed by the year of middle value, followed by year of highest value. See sample input below. This is followed by a sample output.

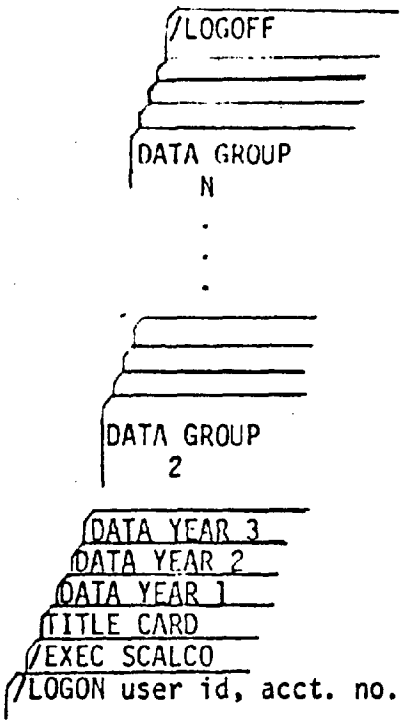
```
OLUMS
         1    1    2    2    3    3    4
    5    0    5    0    5    0    5    0

                              V-- TITLE CARD
                              V
EST RUN FOR SCALE CONVERSION PROGRAM

                              V-- DATA CARDS
                              V
 .5   .45   10 .696  .696  .696  .696  .696  .696  .696  .696  .696  .696
.49   .45   10 .694  .694  .694  .694  .694  .694  .694  .694  .694  .694
.75   .45   10 .996  .996  .996  .996  .996  .996  .996  .996  .996  .996
```

NOTE: all data values must contain decimal points, except the data values in columns 1-2 and 18-19. These values must be right justified, that is, the units position is the right most position of the field and the tens position is the next position to the left.

JOB CONTROL STRUCTURE



The above illustrates how several groups of data would be submitted in a single run. Remember /LOGOFF must always be the last card.

SEC 01 OHIO LINE TO ELMWOOD ROAD SPRINGFIELD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR

	1	2	3	4	5	6	7	8
38	0.142	0.235	0.227	0.186	0.130	0.232	0.195	0.115
59	0.131	0.214	0.232	0.165	0.111	0.209	0.177	0.090
74	0.167	0.291	0.312	0.240	0.138	0.305	0.247	0.130

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR SCALE

		1	2	3	4	5	6	7	8
38	20986.9	2980.1	4931.9	4764.0	3903.6	2728.3	4869.0	4092.5	2413.5
59	21144.6	2769.9	4524.9	4905.6	3488.9	2347.1	4419.2	3742.6	1903.0
74	13782.9	2301.7	4010.8	4300.2	3307.9	1902.0	4203.8	3404.4	1791.3

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR

	1	2	3	4	5	6	7	8
38 - 59	210.2	407.0	-141.5	414.7	381.2	449.7	349.9	510.5
59 - 74	468.2	514.1	605.3	181.0	445.0	215.5	338.2	111.2
38 - 74	678.4	921.1	463.8	595.7	826.3	665.2	688.1	621.7

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR

	1	2	3	4	5	6	7	8
38 - 59	10.0	19.4	-6.7	19.7	18.2	21.4	16.7	24.3
59 - 74	31.2	34.3	40.4	12.1	29.7	14.4	22.5	7.4
38 - 74	18.8	25.6	12.9	16.5	23.0	18.5	19.1	17.3
	78.3	106.7	53.7	68.7	95.8	77.0	79.6	72.1

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5	6	7	8
1811.8	3345.6	3965.3	2877.7	1305.3	3723.3	2907.4	1342.7

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4	5	6	7	8
490.0	665.3	335.0	430.2	596.7	480.4	497.0	449.0

SEC 02 RACCOON CREEK TO CAMP LAMSEC SPRINGFIELD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5	6	7	8
38	0.254	0.260	0.223	0.271	0.433	0.550	0.870	0.985
59	0.210	0.239	0.208	0.241	0.401	0.549	0.880	0.993
74	0.276	0.325	0.281	0.331	0.571	0.785	1.254	1.414

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5	6	7	8
38	20370.9	5174.2	5296.4	4542.7	5520.5	9820.6	11204.0	17722.6	20065.3
59	20082.7	4217.4	4799.8	4177.2	4839.9	8053.2	11025.4	17672.8	19942.1
74	14003.0	3864.8	4551.0	3934.9	4635.0	7995.7	10992.4	17559.8	19800.3

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5	6	7	8
38 - 59	956.8	496.7	365.5	680.6	767.4	178.6	49.9	123.2
59 - 74	352.5	248.8	242.3	204.9	57.4	33.0	113.0	141.6
38 - 74	1309.4	745.4	607.8	885.5	824.8	211.6	162.8	265.0

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5	6	7	8
38 - 59	45.6	23.7	17.4	32.4	36.5	8.5	2.4	5.9
59 - 74	23.5	16.6	16.2	13.7	3.8	2.2	7.5	9.5
38 - 74	36.4	20.7	16.9	24.6	22.9	5.9	4.5	7.4
	154.67	86.3	70.4	102.50	95.42	24.58	18.7	30.83

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5	6	7	8
2919.2	4012.6	3495.9	3995.5	7400.0	10839.6	17442.2	19608.9

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

SEC 03 CROOKED CREEK VICINITY SPRINGFIELD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
38	0.580	0.599	0.684	0.730
59	0.595	0.617	0.674	0.723
74	0.838	0.886	0.993	1.007

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
38	21683.8	12576.6	12980.6	14831.7	15829.1
59	21035.8	12516.3	12979.1	14178.2	15208.9
74	14251.0	11942.3	12626.4	14151.2	14350.8

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
38 - 59	60.3	9.5	653.5	620.2
59 - 74	574.0	352.7	26.9	858.2
38 - 74	634.2	362.2	680.4	1473.4

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
38 - 59	2.9	0.5	31.1	29.5
59 - 74	38.3	23.5	1.8	57.2
38 - 74	17.6	10.1	18.9	41.1
	73.33	42.1	78.7	171.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
11484.3	12364.8	13659.8	13283.0

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
458.1	261.6	491.4	1067.7

SEC 04 CAMP SEQUOYAH VICINITY SPRINGFIELD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2
39	1.126	1.957
59	1.135	1.970
74	1.661	2.875

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2
39	21265.8	23945.3	41617.2
59	21065.8	23909.7	41499.7
74	14359.0	23850.2	41282.0

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2
39 - 59	35.6	117.5
59 - 74	59.5	217.6
39 - 74	95.1	335.2

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2
39 - 59	1.8	5.9
59 - 74	4.0	14.5
39 - 74	2.7	9.6
	11.3	40.0

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2
23779.6	41033.0

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2
70.6	249.0

SEC 05 CAMP SECUOYAH TO E OF ELK CREEK GIRARD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2
39	1.920	2.010
59	1.864	1.920
74	2.871	2.898

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2
39	21003.7	40327.1	42217.5
59	21240.0	39591.4	40780.8
74	14008.2	40217.7	40595.9

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2
39 - 59	735.8	1436.7
59 - 74	-626.3	184.9
39 - 74	109.5	1621.6

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2
39 - 59	36.8	71.8
59 - 74	-41.8	12.3
39 - 74	3.1	46.3
	18.9	192.92

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2
40136.3	39391.3

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2
81.3	1204.6

SEC 06 ELK CREEK TO LAKE ERIE COMMUNITY PARK GIRARD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5
38	1.187	1.133	1.068	1.115	1.072
59	1.193	1.122	1.063	1.110	1.067
74	1.647	1.698	1.575	1.640	1.580

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5
38	20424.7	24244.1	23141.2	21813.6	22773.5	21895.3
59	20496.4	24454.5	22999.1	21789.7	22753.2	21871.6
74	13567.7	22346.0	23038.0	21369.1	22251.0	21437.0

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5
38 - 59	-210.4	142.0	23.8	20.4	23.5
59 - 74	2108.5	-38.8	420.6	502.1	434.8
38 - 74	1898.1	103.2	444.4	522.5	458.3

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5
38 - 59	-10.0	6.8	1.1	1.0	1.1
59 - 74	140.6	-2.6	28.0	33.5	29.0
38 - 74	52.7	2.9	12.3	14.5	12.7
	219.58	12.1	51.3	60.4	52.9

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5
20975.2	22963.4	21048.1	21973.7	21106.0

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4	5
1370.9	74.5	321.0	377.4	331.0

SEC 07 LAKE ERIE COMMUNITY PARK TO CAMP CALEDON GIRARD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	1.079	1.088	0.944	1.100
59	1.143	1.143	0.981	1.163
74	1.730	1.666	1.455	1.751

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	21355.1	23042.1	23234.3	20159.2	23490.6
59	20123.1	23000.7	23000.7	19740.7	23403.1
74	13279.2	22973.0	22123.1	19321.2	23251.9

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	41.5	233.7	418.5	87.5
59 - 74	27.7	877.5	419.5	151.3
39 - 74	69.2	1111.2	838.0	238.8

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	2.1	11.7	20.9	4.4
59 - 74	1.8	58.5	28.0	10.1
39 - 74	2.0	31.7	23.9	6.8
	8.3	130.)	99.1	28.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
22921.6	21297.6	18698.7	23074.5

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
51.4	825.5	622.5	177.4

SEC 08 CAMP CALEDON TO CAMP SHERWIN GIRARD TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	1.331	1.419	1.609	1.783
59	1.367	1.462	1.624	1.841
74	2.041	2.183	2.474	2.751

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	21818.2	29040.0	30960.0	35105.4	38901.9
59	21126.8	28880.3	30887.3	34943.7	38894.4
74	14117.6	28814.1	30818.8	34927.1	38837.7

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	159.7	72.6	161.8	7.4
59 - 74	66.2	68.5	16.6	56.7
39 - 74	225.9	141.2	178.4	64.1

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	8.0	3.6	8.1	0.4
59 - 74	4.4	4.6	1.1	3.8
39 - 74	6.5	4.0	5.1	1.8
	27.1	16.7	21.3	7.5

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
28646.3	30714.0	34794.5	38790.0

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
167.8	104.9	132.5	47.6

SEC 09 A MELHURNE ROAD TO EATON ROAD FAIRVIEW TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2
39	0.246	0.090
59	0.244	0.088
74	0.357	0.121

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2
39	20987.2	5162.8	1888.8
59	21137.9	5157.7	1860.1
74	14146.1	5050.2	1711.7

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2
39 - 59	5.2	28.7
59 - 74	107.5	148.5
39 - 74	112.7	177.2

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2
39 - 59	0.3	1.4
59 - 74	7.2	9.9
39 - 74	3.2	5.1
	13.3	31.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2
4966.5	1580.1

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2
83.7	131.6

SEC 09 B MELHORNE ROAD TO EATON ROAD FAIRVIEW TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5
39	0.000	0.000	2.733	2.726	0.375
59	0.000	0.000	2.718	2.726	0.374
74	0.000	0.000	3.961	4.056	0.552

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5
39	21150.9	0.0	0.0	57805.4	57657.4	7931.6
59	21140.3	0.0	0.0	57459.3	57628.4	7906.5
74	14181.4	0.0	0.0	56456.3	57519.9	7828.2

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5
39 - 59	0.0	0.0	346.2	29.0	25.1
59 - 74	0.0	0.0	1002.9	108.4	78.3
39 - 74	0.0	0.0	1349.1	137.4	103.4

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5
39 - 59	0.0	0.0	17.3	1.4	1.3
59 - 74	0.0	0.0	66.9	7.2	5.2
39 - 74	0.0	0.0	38.5	3.9	3.0
			160.4	16.3	12.5

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5
0.0	0.0	55454.2	57417.9	7751.3

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

SEC 10 A WALNUT CREEK TO WILKINS ROAD MILLCREEK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	0.562	1.995	1.936	1.864
59	0.569	2.015	1.958	1.881
74	0.857	3.038	2.896	2.791

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	21535.9	12103.2	42964.2	41693.5	40143.0
59	21230.8	12080.3	42780.0	41569.8	39935.0
74	14040.2	12032.4	42654.0	40660.3	39186.1

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	22.9	184.2	123.7	207.9
59 - 74	47.9	126.0	909.5	749.0
39 - 74	70.8	310.2	1033.3	956.9

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	1.1	9.2	6.2	10.4
59 - 74	3.2	8.4	60.6	49.9
39 - 74	2.0	8.9	29.5	27.3
	8.3	37.1	122.9	113.7

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
11979.8	42423.6	39892.7	38475.2

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
52.6	230.4	767.6	710.8

SEC 10 B CONTINUED TO WILKINS ROAD

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5	6
39	0.000	0.000	0.000	0.000	1.840	0.609
59	0.000	0.000	0.000	0.000	1.875	0.616
74	0.000	0.000	0.000	0.000	2.670	0.881

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5	6
39	21324.5	0.0	0.0	0.0	0.0	39237.1	12986.6
59	20619.0	0.0	0.0	0.0	0.0	38660.6	12701.3
74	14396.4	0.0	0.0	0.0	0.0	38438.4	12683.2

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5	6
39 - 59	0.0	0.0	0.0	0.0	576.5	285.3
59 - 74	0.0	0.0	0.0	0.0	222.2	18.1
39 - 74	0.0	0.0	0.0	0.0	798.6	303.4

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5	6
39 - 59	0.0	0.0	0.0	0.0	28.8	14.3
59 - 74	0.0	0.0	0.0	0.0	14.8	1.2
39 - 74	0.0	0.0	0.0	0.0	22.8	8.7
					95.6	36.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5	6
0.0	0.0	0.0	0.0	37845.2	12457.9

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4	5	6

SEC 11 A WILKINS ROAD TO MONTEPELIER AVE MILLCREEK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2
39	1.142	1.402
59	1.191	1.455
74	1.748	2.126

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2
39	21406.1	24445.8	30011.4
59	20510.5	24427.9	29842.7
74	13955.9	24394.9	29670.2

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2
39 - 59	17.8	168.7
59 - 74	33.1	172.5
39 - 74	50.9	341.2

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2
39 - 59	0.9	8.4
59 - 74	2.2	11.5
39 - 74	1.5	9.7
	6.3	40.4

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2
24357.0	29416.7

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2
37.8	253.4

SEC 11 B WILKINS ROAD TO MONTEPELIER AVE MILLCREEK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	0.000	0.000	1.286	1.058
59	0.000	0.000	1.312	1.082
75	0.000	0.000	1.176	0.990

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	21924.3	0.0	0.0	28063.1	23195.9
59	21015.5	0.0	0.0	27572.4	22738.8
75	22915.3	0.0	0.0	26948.3	22686.1

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	0.0	0.0	490.7	457.1
59 - 75	0.0	0.0	624.1	52.7
39 - 75	0.0	0.0	1114.8	509.8

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	0.0	0.0	24.5	22.9
59 - 75	0.0	0.0	39.0	3.3
39 - 75	0.0	0.0	31.0	14.2

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
0.0	0.0	26174.2	22332.1

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4

SEC 12 A MONTEPELIER AVE TO WALDAMEER PARK MILLCREEK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2
38	1.144	1.006
59	1.145	1.010
75	1.032	0.905

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2
38	20843.0	23844.4	20968.1
59	20326.5	23273.9	20529.8
75	22896.5	23629.2	20721.4

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2
38 - 59	570.6	438.3
59 - 75	-355.3	-191.6
38 - 75	215.2	246.7

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2
38 - 59	27.2	20.9
59 - 75	-22.2	-12.0
38 - 75	5.8	6.7
	24.2	97.9

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2
23483.8	20554.7

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2
145.4	166.7

SEC 12 B MONTEPELIER AVE TO WALDAMEER PARK MILLCREEK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
38	0.000	0.000	0.146	1.297
59	0.000	0.000	0.141	1.284
75	0.000	0.000	0.122	1.126

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
38	19970.1	0.0	0.0	2915.6	25901.3
59	20120.3	0.0	0.0	2837.0	25834.5
75	22920.8	0.0	0.0	2796.3	25808.8

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
38 - 59	0.0	0.0	78.7	66.8
59 - 75	0.0	0.0	40.6	25.7
38 - 75	0.0	0.0	119.3	92.5

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
38 - 59	0.0	0.0	3.7	3.2
59 - 75	0.0	0.0	2.5	1.6
38 - 75	0.0	0.0	3.2	2.5

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
0.0	0.0	2715.7	25746.3

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

SEC 13 A HAMMERMILL PAPER CO. TO FOUR MILE CREEK LAWRENCE PARK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3
39	1.290	1.287	1.372
59	1.297	1.297	1.404
75	1.157	1.152	1.226

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3
39	20568.5	26533.4	26471.7	28220.0
59	20394.9	26452.2	26452.2	28634.5
75	22943.1	26429.5	26315.3	28005.6

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3
39 - 59	81.2	19.4	-414.5
59 - 75	22.8	137.0	628.8
39 - 75	103.9	156.4	214.3

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3
39 - 59	4.1	1.0	-20.7
59 - 75	1.4	8.6	39.3
39 - 75	2.9	4.3	6.0
	12.1	17.9	25.0

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3
26357.3	26206.7	27856.8

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3
72.2	108.6	148.8

SEC 13 B HAMMERMILL TO FOUR MILE CREEK

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5
39	0.000	0.000	0.000	1.493	1.359
59	0.000	0.000	0.000	1.505	1.368
75	0.000	0.000	0.000	1.335	1.168

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5
39	20741.2	0.0	0.0	0.0	30966.6	28187.3
59	20495.2	0.0	0.0	0.0	30845.3	28037.4
75	23001.7	0.0	0.0	0.0	30707.2	26866.0

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5
39 - 59	0.0	0.0	0.0	121.3	149.9
59 - 75	0.0	0.0	0.0	138.0	1171.5
39 - 75	0.0	0.0	0.0	259.4	1321.3

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5
39 - 59	0.0	0.0	0.0	6.1	7.5
59 - 75	0.0	0.0	0.0	8.6	73.2
39 - 75	0.0	0.0	0.0	7.2	36.7

30.0 52.92

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5
0.0	0.0	0.0	30527.1	25948.4

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4	5

SEC 14 LOWRY ROAD TO SIX MILE CREEK LAWRENCE PARK TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5	6
39	0.203	1.156	0.736	0.603	0.449	0.567
59	0.230	1.153	0.772	0.532	0.464	0.561
75	0.176	1.037	0.649	0.524	0.392	0.496

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5	6
39	20780.1	4218.4	24021.8	15294.2	12530.4	9330.3	11782.3
59	20424.9	4697.7	23549.9	15768.0	10866.0	9477.2	11458.4
75	23073.1	4060.9	23926.8	14974.4	12090.3	9044.7	11444.3

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5	6
39 - 59	-479.4	471.9	-473.9	1664.4	-146.9	324.0
59 - 75	636.9	-376.9	793.6	-1224.3	432.5	14.1
39 - 75	157.5	95.0	319.7	440.1	285.6	338.1

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5	6
39 - 59	-24.0	23.6	-23.7	83.2	-7.3	16.2
59 - 75	39.8	-23.6	49.6	-76.5	27.0	0.9
39 - 75	4.4	2.6	8.9	12.2	7.9	9.4
	18.3	10.8	37.1	50.8	32.9	39.2

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5	6
3951.5	23960.8	14752.4	11784.7	8846.3	11209.5

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4	5	6
109.4	66.0	222.0	305.6	198.3	224.8

SEC 15 SEVEN MILE CREEK TO EAST OF EIGHT MILE CREEK HARBORCREEK TWP.

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4	5
39	1.036	0.852	0.906	0.530	0.507
59	1.015	0.826	0.915	0.506	0.496
75	0.913	0.756	0.804	0.466	0.448

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4	5
39	20879.0	21630.6	17788.9	18916.3	11065.8	10585.6
59	21089.9	21406.3	17420.3	19297.3	10671.5	10460.6
75	23277.3	21252.2	17597.7	18715.0	10847.2	10428.2

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4	5
39 - 59	224.3	368.6	-380.9	394.3	125.0
59 - 75	154.1	-177.4	582.3	-175.7	32.4
39 - 75	378.4	191.2	201.4	218.6	157.4

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4	5
39 - 59	11.2	18.4	-19.0	19.7	6.3
59 - 75	9.6	-11.1	36.4	-11.0	2.0
39 - 75	10.5	5.3	5.6	6.1	4.4
	48.7	92.1	93.3	95.4	18.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4	5
20989.4	17464.9	18575.1	10695.4	10318.9

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4	5
262.8	132.8	139.8	151.8	109.3

SEC 16 HIGHMEYER ROAD TO NORTHEAST TWP. LINE HARBORCREEK TWP.

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	0.289	0.460	0.719	0.834
59	0.278	0.456	0.715	0.836
75	0.295	0.414	0.646	0.728

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	20899.1	6039.8	9613.6	15026.4	17429.8
59	20843.8	5794.6	9504.8	14903.3	17425.4
75	22972.7	5858.0	9510.7	14840.4	16724.2

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	245.3	108.8	123.2	4.5
59 - 75	-63.5	-6.0	62.9	701.2
39 - 75	181.8	102.9	186.1	705.7

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	12.3	5.4	6.2	0.2
59 - 75	-4.0	-0.4	3.9	43.8
39 - 75	5.0	2.9	5.2	19.6
	20.83	12.1	21.67	81.7

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
5731.8	9439.3	14711.2	16234.1

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
126.2	71.4	129.2	490.1

SEC 17 NORTHEAST TWP. LINE TO BRICKYARD ROAD NORTHEAST TWP.

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3
38	0.535	0.126	0.201
59	0.491	0.088	0.178
75	0.445	0.091	0.164

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3
38	19379.3	10367.9	2441.8	3895.2
59	20374.6	10003.9	1792.0	3626.7
75	22349.6	9945.6	1810.3	3665.3

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3
38 - 59	364.0	648.8	268.6
59 - 75	58.4	-17.4	-38.7
38 - 75	422.3	631.5	229.9

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3
38 - 59	17.3	30.9	12.8
59 - 75	3.6	-1.1	-2.4
38 - 75	11.4	17.1	6.2
	47.50	71.3	25.83

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3
9660.2	1383.6	3510.0

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3
285.4	426.7	155.3

SEC 18 CEMETERY ROAD AREA NORTHEAST TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	0.348	0.107	0.216	0.168
59	0.354	0.088	0.221	0.168
75	0.292	0.087	0.186	0.148

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	20646.7	7185.0	2209.2	4459.7	3468.6
59	20267.9	7174.8	1783.6	4479.2	3405.0
75	22970.3	6707.3	1998.4	4272.5	3399.6

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	10.2	425.6	-19.5	63.6
59 - 75	467.5	-214.8	206.7	5.4
39 - 75	477.7	210.8	187.2	69.0

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	0.5	21.3	-1.0	3.2
59 - 75	29.2	-13.4	12.9	0.3
39 - 75	13.3	5.9	5.2	1.9
	55.4	24.6	21.7	7.9

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
6375.6	1852.0	4142.5	3351.7

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
331.7	146.4	130.0	47.9

SEC 19 SIXTEEN MILE CREEK TO TWENTY MILE CREEK NORTHEAST TOWNSHIP

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2	3	4
39	0.554	0.444	0.562	0.648
59	0.602	0.499	0.595	0.707
75	0.535	0.422	0.538	0.631

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2	3	4
39	22488.3	12458.5	9984.8	12638.4	14572.4
59	20448.2	12309.8	10203.7	12248.5	14456.9
75	22982.8	12295.8	9698.7	12364.7	14502.1

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2	3	4
39 - 59	148.7	-218.9	389.9	115.5
59 - 75	14.0	504.9	-116.3	-45.2
39 - 75	162.7	286.0	273.7	70.2

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2	3	4
39 - 59	7.4	-10.9	19.5	5.8
59 - 75	0.9	31.6	-7.3	-2.8
39 - 75	4.5	7.9	7.6	2.0
	8.25	32.9	31.7	8.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2	3	4
12182.8	9500.1	12174.7	14453.4

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2	3	4
113.0	196.6	190.0	48.8

SEC 20 TWENTY MILE CREEK TO NEW YORK STATE LINE

DISTANCE FROM REFERENCE LINE (MAP INCHES)

FOR YEAR	1	2
38	0.752	0.212
59	0.729	0.204
75	0.633	0.151

DISTANCE FROM REFERENCE LINE (ACTUAL INCHES)

FOR YEAR	SCALE	1	2
38	20297.4	15263.7	4303.1
59	21224.0	15472.3	4329.7
75	23306.7	14753.1	3519.3

DISTANCE DIFFERENCES (ACTUAL INCHES)

FOR YEAR	1	2
38 - 59	-208.6	-26.6
59 - 75	719.1	810.4
38 - 75	510.5	783.7

AVERAGE DIFFERENCE DISTANCE (ACTUAL INCHES/YEAR)

FOR YEAR	1	2
38 - 59	-9.9	-1.3
59 - 75	44.9	50.6
38 - 75	13.8	21.2
	57.5	88.3

DISTANCE FROM REFERENCE LINE IN YEAR 2000 (ACTUAL INCHES)
BASED ON AVERAGE OF FIRST AND LAST YEARS

1	2
14408.2	2989.8

DISTANCE DIFFERENCE BETWEEN YEAR 2000 AND LAST YEAR (ACTUAL INCHES)

1	2
345.0	529.6

APPENDIX D

PROPERTY OWNER SURVEY

A survey of shoreline property owners was conducted as a part of the study. A copy of the cover letter and the survey form is included in the following pages. Names and addresses were obtained from the computerized printout of tax assessment data maintained by the County. Only 25 out of 710 or 3.5% were returned by the Post Office because of out-of-date addresses or owner's names.

There are approximately 710 separate owners of lakeshore property. Only those properties were selected which have Lake Erie as a northern boundary. There are also nine lakefront properties which contain approximately 110 rental cottages or mobile homes which are not included in the total of 710. Thus, there are an estimated 343 permanent residences and 437 summer residences which front directly on the lake. There are also nine summer camps which contain temporary housing that is not included in these totals (however, camp buildings which are in the hazard areas have been included in the figures elsewhere in this report which show the number of structures in danger). Bayshore owners were not included in the survey because their properties are protected by Presque Isle and generally fall in the limited hazard category. A general summary of lakefront ownership patterns was obtained from an analysis of the list of lakeshore property owners. See the next page for this summary.

The following highlights of ownership patterns are significant:

(1) Somewhat higher density shoreline development in the East County (406 owners) as compared to West County (284 owners).

(2) A greater proportion of permanent residential owners than is generally assumed by the public.

(3) A high proportion of local (Erie County)ownership (86%).

(4) Most (an estimated 75%) of the owners of summer cottages who live in Erie County are residents of the City of Erie. This fact does not show as a separate statistic in the summary, but can be verified by a detailed analysis of addresses.

The letter and survey were mailed during the last two weeks in April, 1975. By June 11, 1975, 144 responses (20.3% of 710 total owners) had been returned. Thirty-two respondents enclosed pictures, diagrams, or survey plots. Following is a summary of use patterns for the respondents (135 usable responses). Ninety percent of the respondents indicated some erosion, recession, or damage to their property.

The most significant information contained in the responses concerns the loss of valuable beach area over the past three years. Practically all respondent listed beach erosion of 20 to 100 feet. Many owners reported the loss of boathouses, trees, water systems, and stairways which had been swept away from the beach by storms. This beach erosion not only greatly reduced the usefulness of the property, but also left the toe of the bluff unprotected and extremely vul-

TOWNSHIP	PERMANENT RESIDENTIAL	SUMMER RESIDENTIAL					
		TOWNSHIP RESIDENT	OTHER ERIE COUNTY	PITTSBURGH AREA	OTHER PA	OTHER STATES	OTHER USES
Springfield 47	8	-	20	8	-	5	6 plus 54 rental units
GIRARD (LAKE CITY BORO) 41	13	4	16	2	-	1	5 plus 12 rental units
FAIRVIEW 80	49	-	25	-	-	4	2
MILLCREEK 116	26	14	43	24	1	4	4 plus 10 rental units
ERIE 20	14	-	-	-	-	-	6
LAWRENCE PARK 27	21	-	-	-	-	-	6
HARBORCREEK 115	100	5	38	1	1	3	7 plus 12 rental units
NORTH EAST 224	112	26	45	27	1	9	4 plus 24 rental units
TOTALS 710	343	49	187	62	3	26	(including 40 34 Erie County owners) plus 112 rental units

GREAT LAKES RESEARCH INSTITUTE
155 WEST EIGHTH STREET, ERIE, PA. 16501

April, 1975

Dear Property Owner:

Great Lakes Research Institute (GLRI) is working under contract for the Pennsylvania Department of Environmental Resources to identify Lake Erie coastal hazard areas. The intent of the project is to identify Erie County, Pa. shoreline areas subject to bluff recession, shore erosion, or lake flooding. Such hazard areas, as you know, are subject to damages caused by storm surge, high water levels, ice action, and ground water seepage.

We are gathering information from topographic maps, aerial photographs, and on-site reconnaissance from the ground, air, and off-shore. Additionally, we would like to collect any information that shore property owners may have concerning their particular property.

Specifically, we would appreciate it if you could furnish us with any of the following data:

1.) Current or historical maps, photographs, or surveys of shoreline and bluff areas on your property.
2.) Information on location and construction of erosion control structures or projects.
3.) Information on land, buildings, or erosion control structures damaged or destroyed in the past forty (40) years along the shoreline. However, we are most interested in such damage during the past three (3) years.

In that regard, we would very much appreciate it if you would fill in the enclosed survey and return it at your earliest convenience. Please fill in only those items which pertain to your property. Thank you very much for your co-operation. Please feel free to contact me if you have any questions.

Sincerely,

G. Rodger Crowe

G. Rodger Crowe
Program Manager

Area Code 814 . 453-5068

SURVEY OF SHORELINE PROPERTY OWNERS

1. Name_____

   Mailing Address_____

   _____

2. Extent of Property

   Shoreline Width_____

   Lot Depth_____

3. Shoreline Characteristics

   _____Beach -- Width_____

   Depth_____

   _____Bluff -- Width_____

   Height_____

   _____Stream Outlet

   _____Other (Describe)_____

   _____

4. Location of Shoreline Property

   _____
   Road or Street

   _____
   Township

   Cottage Association or Subdivision

   _____

5. Use of Property

   _____Permanent Residential

   _____Summer Residential

   _____Agriculture (List Crops)

   _____

   _____

   _____Private Park or Camp

   _____Public Park or Camp

   _____Industrial (List Products)

   _____

   _____

   _____Other (Describe)

   _____

   _____

6. Number and Type of Buildings Subject to Possible Damage (include distance to bluff edge or shoreline).

   _____

   _____

7. Please describe erosion control measures or structures built or maintained by property owner (breakwalls, groins, rockfill, sandfill, vegetation cover, etc.). Please list date of construction and present condition. _____

_____

_____

_____

8. DESCRIPTION OF DAMAGES SINCE 1972 (Use Back of Page for Additional Remarks or Damage Information Prior to 1972):

a.) Extent of Beach Damage (Width & Depth) _____

_____

b.) Extent of Bluff Recession or Erosion (Width & Depth) _____

_____

c.) Extent of Damage to Erosion Control Structures _____

_____

d.) Extent of Other Damage (Docks, Boathouses, Stairways, Landscaping, Trees, Water Systems, or Sewer Systems) _____

_____

Other data or comments:

_____

_____

_____

Please feel free to send photographs, maps, or diagrams to illustrate the above informat (Such items will be returned to you if specifically requested). Thank you for your assi

Please return this survey to: Rodger Crowe
Great Lakes Research Institute
155 West Eighth Street
Erie, Pennsylvania 16501

SURVEY RESPONDENTS

USE OF PROPERTY

TOWNSHIP	PERMANENT RESIDENTIAL	SUMMER RESIDENTIAL	OTHER
SPRINGFIELD 9	2	5	2
GIRARD (Lake City Borough) 8	4	3	1
FAIRVIEW 11	9	2	-
MILLCREEK 22	4	18	-
ERIE 7	3	1	3
LAWRENCE PARK 7	7		-
HARBORCREEK 23	16	6	1
NORTH EAST 48	26	18	4
TOTALS 135	71	53	11

nerable to wave attack. With the bluff subject to wave attack and toe erosion, there are many owners that now have a sheer dropoff of five to 30 feet which severely limits their access to the beach.

All reaches of shoreline in the county have been subject to damage and this is reflected in the data and comments contained in the responses. The following pages contain practically all of the important comments made by property owners. The comments are grouped by township and are listed in geographical order, west to east.

SPRINGFIELD TOWNSHIP

"We lost at least 20 ft. of beach as then and now photos show ... lost boathouse and stairs that we used to have on beach. Built new beach house near cottage."

"Pier and wall made of railroad ties ... 20 ft. of pier missing; two walls gone .... Soil is clay. After a bad storm, rain will cause bank to slide."

"Twenty years ago, owner of land built three cement piers out into the water. They are now under water because of the high water and of no use when fall and spring storms come ...(Beach Damage) lost about 5 ft. ... (Bluff Recession) lost about 10 ft. ... Lost stairway, several large trees. Next door lost dock with a water system .... I believe that someone can control the high water. If this isn't done, we and several others will lose our cottages."

"Concrete pier built about 1955, still in good condition, 90 ft. long by 7 ft. wide."

"Approximately 40-45 ft. (Bluff) recession along length of property."

"Eight cottages near lake moved back to avoid storm damage ... 20 to 40 ft. of beach has disappeared into the lake ... about 20 ft. of bluff has fallen away ... at least 25-50 trees have been destroyed as well as cement patios, beach-front walks, walls, etc. have been destroyed."

"Beach had become non-existent until jetties were built."

"Three 150 ft. concrete piers - they are all three in good condition, however, high water conditions have made them almost worthless .... In the past four years, we have lost a beautiful beach that ran the length of our property and varied 30 to 100 ft. in depth ... (Bluff Recession) width 1,000 ft.; depth of loss 100 ft."

GIRARD TOWNSHIP

"Have lost entire boat launching ramp and two large willow trees."

"Three years ago, our Lakefront property was a gradual sloping hillside to the beach. We had a path down the hillside which we could walk to the beach. Our beach was 35 ft. wide at that time. Now we have no beach; the lake has undermined our hillside and washed it away so that we now have a 10 ft. high bluff. It has washed 15 ft. of our hillside away and has started a landslide which has worked back 80 ft. on our property."

"Thirty years ago, we had about 300 ft. of land between water and bluff; now that has eroded to about 30 ft."

"(Beach Damage) 700 ft. full length has been lost last 3-5 years ... (Bluff Recession 700 ft. full length has been lost about 10-20 ft. in depth."

"(Beach Damage) 50 ft. entire length ... (Bluff Recession) 20 ft. entire length."

"We had a cement wall parallel to lake - 150 ft. length x 6 ft. height ... 60 years old ... now is broken up, laying on side out in the lake ... no protection ... (Erosion Control Structures) completely destroyed ... destroyed all trees, shrubs, flowers, hand cut stone steps."

"Piers built 8-9 years ago. East pier 125 ft. initially ... lost 16 ft. West pier 50 ft. .... Lost 8 ft. two years ago. Breakwall put in 1974 at base of bluff varies in height from 6-10 ft. ... vegetation cover - rye, crown vetch, black locust trees. Present condition is just fair - property on east of east pier is badly eroding .... Lost 10 ft. of bluff over period of 10 years. .... East of pier (bluff) erosion very bad ... piers have helped, but not sufficiently to recommend the investment."

FAIRVIEW TOWNSHIP

"Tried crown vetch several times (as erosion control measures) ... (Bluff Recession) 135 ft. wide - have lost about 10-12 ft. in past 15 years ... some trees eroded and fallen over bluff."

"Planted bristly locusts each spring for the last 5 years from top of bluff towards center ... (Bluff Recession) 68 ft. wide x 75 ft. deep ... lost 15 grown trees and other vegetation on bluff ... spring water seeping from center of bluff seems to be cause of some erosion."

"Planted multiflora at top of bluff to prevent crumbling ... also trees. Most planting done in early 1960's. Hedge is mostly gone ... original beach completely gone (244 ft. x 40 ft.) ... steps from top of bluff to beach are half gone .... Originally this was more like a steep bank than a bluff. Now it is approaching the bluff stage. As for the beach, we had about 40 ft. in depth and now have about 10 ft., but the whole thing has moved back so that none of that is part of the original beach."

"Homemade cement blocks; used tires interlaced and anchored; rocks in places on shoreline (Erosion control measures). We have topped trees, trimmed trees to let in sunlight and permit vegetation to grow."

"Locust trees on one side; have tried trees on front, vegetation cover, etc. 1958-66 construction, a little at a time. Good condition - block and bricks. Have lost 25-30 ft. of bank since 1958 ... (Bluff Recession) about 80 ft. width and 6-10 ft. depth ... I would say we lose from 2-3 ft. a year average.

"(Beach Damage) cut away several feet of lawn during heavy wind storm (180 ft. width x 6 ft. depth) .... No structures on my property, but property immediately east - had stone breakwall broken."

"Pier completely destroyed by storm in spring of 1970 .... Walnut Creek jetty appears to be helping some, although we are approximately 1,200 ft. west."

"Natural tree growth to water's edge. Breakwater constructed off an adjacent property in 1974 ... (Bluff Recession) 200 ft. width x 25 ft."

"With 3-4 ft. higher water level - beach has disappeared and water eroded above the level of shale ... (Bluff Recession) 100 ft. width; 20 ft. depth."

"(Beach Damage) 200 ft. wide x 50 ft. deep ... (Bluff Recession) 10 ft. to 15 ft. entire width sliding ... trees sliding ... water pump and well destroyed."

"Beach much narrower and covered with fallen trees .... Extensive damage (to bluff) at beach level, with four tiers of "slippages" producing a terraced effect .... Water system, previously from beach, has been destroyed. Many large trees at foot of bluff have fallen along with erosion and slippage of bank."

MILLCREEK TOWNSHIP

"Gas well drilled 35 years ago 100 ft. from water's edge now head exposed mid-beach, subject to destruction by wave action during severe storms on lake ... (Beach Damage) gradual erosion by lake by perhaps 50 ft. from 1900-1972, and an additional 40 ft. since."

"(Beach) completely gone ... (Bluff) approximately total of two acres of land/foilage/trees lost ... loss of lower half of stairways approximately 60 ft., numerous large trees (2/3 ft. in diameter)."

"Breakwall undermined and overtopped ... boathouse five feet inside breakwall undermined - torn down by owner in 1975. Septic tank damaged."

"(Erosion control measures) breakwall, groins ... 1973 and 1974 wave action ruined groins ... broke up and washed groin, broke up seawall and concrete deck."

"The past two years we have planted rye in the eroded areas. First year's planting was completely lost .... Between 8 and 10 ft. of our bluff has fallen into the lake .... The waves have eroded away the earth underneath our steps; also, our boathouse was completely destroyed."

"Winter of 1972-73 there was considerable damage to seawall from storms."

"Front end of boathouse bashed in during winter storms of past years. Sand, gravel and stones usually washed over breakwall during winter storms necessitating cleaning up after storms."

"Dock (groin) washed out - 30 ft. ... 1972-73 stairway, landscaping washed out - 6 ft. depth; severe breakwall damage ... 80 ft. of beach area in 1967 - trucks and vehicles could drive across front at that time .... In my opinion, the two greatest factors causing problems in stream runoff which is not tubed to shoreline (this also causes loss of thousands of trees), but terminates at tops of bluffs, hills, etc. and also, sand dredgers - four dredgers now operate in an area from Asbury Road to the tip of peninsula, most dredging being performed under the cover of darkness from 9:30 p.m. to 6:45 a.m. as close as 3/4 of a mile off shore. I have over two and one half years actual documentation. Ohio dredgers now dredge

also, just west of Peninsula. Dredging is eliminating the natural protection which "breaks" waves at a safe distance. Waves are now breaking at the shoreline causing a "vacuum" effect in an effort to restore level - this action then accelerates erosion. Dredgers now causing (in my opinion) beach erosion on peninsula by dredging sand and then re-selling this same sand to prevent the problem they cause??? The third cause is increased runoff due to construction of plazas, homes, and natural growth of communities along Lake Erie as well as lake level control."

"My cottage was undermined by Lake Erie on November 26, 1972. No measures had been taken to control, or counteract the action of the lake, as we had seen the devastating effects such efforts had on properties located to the east of them in 1952 (in the Kelso Estate area) by groins which extended into the lake. Immediately to the west, the beach filled in, but to the east the beach was eliminated .... In September, 1972, the (adjacent) property owners ... built groins extending into the lake, without approval of the Corps of Engineers, and with no technical knowledge. Erosion intensified rapidly and in November our cottage was completely destroyed."

"(Beach Damage) 60 ft. wide and all depth are gone .... All trees and one cottage washed away."

"Beach eroded probably 30 ft. resulting in water where there was sandy beach. Sand removed from rest of beach, leaving pebbles and large stones ... base of stairway down bluff eroded away. At least two quite large trees felled by erosion around root structure."

"Built breakwall in front of cottage 30 ft. long in 1972. Still in good condition ... it has saved cottage so far."

"Wave action deposited rocks on patio damaging stone faling, concrete patio steps wrecked, slight damage to porch doors and storage building."

"(Erosion Control Measures) On east side, a line of steel barrels sunk in ground and filled with stones and cement cap. On west side of line, one gabion wire basket 3 x 3 x 12 ft.... I'm told both are in good shape. Drums installed during summer, 1974 - gabion installed fall, 1974."

"Conditions very bad last 5 years; very bad erosion; no sand anymore, all rocks. Have lost 20 feet of depth of beach. Tried everything to prevent it, but am now testing use of wire baskets (gabions) filled with about five tons of flat rocks, laid sideways. Water slams into it, runs through. Last winter (first for basket) was excellent test. Basket, which is 12 ft. long, 3 ft. high, 3 ft. wide, 3 ft. deep, four compartments, took terrific beating but stood up well. Held its own against erosion. Last year our Baer Beach Association purchased 12 gabions (wire baskets), suggested by Army engineers for test. The baskets cost $45 each. They are heavy wire, triple coated to prevent against rusting. We installed one last Fall and the result was amazing. The basket's top is somewhat battered, but we feel it is doing everything it was intended for. We now have five baskets installed on the beach and extending to the lake's edge. It will be interesting to see what happens this winter inasmuch as we have now extended some into the water a few feet. There has been a little rusting, but not too much to speak of as yet. If this thing works it will be a great boon to cottage owners trying to save their shoreline. Up to now, we are well-pleased and would invite anyone to inspect them. Many have already come from other beaches to see what they have done and seem well pleased. We have seven more baskets to install and by then we will have fortified the most badly beaten

strip of shoreline (about 200 ft. long)."

"One wood bungalow. Shoreline up to front steps at times; higher during storms - water comes into porch through door .... Railroad tie wall with steel rods was built in August, 1974. Wall holding up well at present. Northwest side of wall was not completed up to cottage and land in that area was washed away during winter of 1974 and spring of 1975 .... Before 1972, beach extended 100-150 ft. in front of porch front. In 1973 and 1974 water was up to porch steps .... Spring storms of 1974 eroded the three concrete 12 ft. long and 12 ft. wide steps, concrete porch, 30 ft. long and 12 ft. wide, and part of cottage foundation. Foundation and porch were replaced, another storm several weeks later broke up the new porch foundation and was replaced."

"(Erosion Control Measures) Constructed one 50 ft. wall by burying 8 ft. railroad ties 7 ft. deep in a vertical position - fall of 1974 and still there - seems to be OK ... lost 75 ft. of beach 50 ft. wide - endangered cottage."

"Shoreline has receded approximately 20 to 30 ft. in the past few years ... also much of the sand has washed out and been replaced by rock ... some damage to stairways .... The jetty which was installed approximately 20 years ago at extreme east end of property line has over the years built up considerable beach in front of our cottage up until about 3 years ago, when the water level raised so high. Since then we have had trouble maintaining our beach in front of our cottage mainly because the existing jetty is not long enough to build beach far enough west to properly protect our cottage."

"Although, since the construction of the jetty, we have approximately 25 ft. to shoreline, each year sand built up under the cottage has reach a 7 ft. depth. We now have to dig out the front porch and side steps to prevent rot every spring.

"Groin constructed almost 12 years ago and cemented on top about five years ago. Condition - good, and has built substantial beach ... (Beach Damage) not severe for us, but half mile west considerable damage to cottages and breakwalls."

"Pier - built in two sections 1950-65 total length 175 ft. - condition - good, built by and paid for by cottage owners .... By installing pier it has built up beach 100 ft. since 1950. Water used to wash in to property line."

CITY OF ERIE

"Had about 100 ft. of beach, now only about 60 ft."

"Built in 1940 - building OK, but the monorail (boat ramp) was knocked over by water and ice three times in the past five years .... All lawn and trees and landscaping ruined."

"(Bluff Recession) 60 ft. width; 2 ft. to 40 ft. depth .... Lost some trees and bushes."

"Any bank erosion has been slow and gradual. There has been no slippage of the overburden since 1926 (limit of my knowledge). Erosion of the shale rock (lower) portion of the bank appears to progress slowly as a result of freezing and spalding off of the shale, which is in alternate hard and soft layers. I do have a bench-mark. In 1926 my Father built a boathouse on this property at the top of the shale portion of the bank (25 ft. above the water). This was built on a founda-

tion of I-Beams, encased in concrete. The front of the foundation was originally even with the top of the bank. Later the wooden boathouse was removed, but the undation remained. At present (40 years later), the foundation projects about 6 ft. over the bank, indicating that that amount of erosion has taken place in that time."

"No beach protection left ... (Bluff Recession) 100 ft. wide .... Since 1926, 6 ft. of shale rock foundation has eroded .... As shale rock base erodes, the bluff drops into the lake creating the hazard of slides, since quicksand exists on top of the rock shale. During the winter, considerable ice damage is caused on the banks due to lake waves dashing higher than the rock base."

CITY OF ERIE (Hammermill Paper Company Engineering Reports)

"Two major areas of protection have been implemented. Each was designed to reduce or arrest erosion of the shale underlying an essentially clay bluff. Total height of bluff is approximately 50 ft. with the base shale layer having a thickness of about 10 ft. above water level. With recent high lake levels and an absence of ice cover, the underlying shale was being eroded at an alarming rate. The clay overburden was also permeated with water and certain areas were plagued with classical slides.

Area "1" as shown on the plot plan was protected with massive rip rap of compatible sandstone in 1968 at the toe of the bluff and approximately 15 ft. up from the lake bottom. The clay bluff was planted with a combination of grass seeds and crown vetch with excellent results-- no slides or sloughing has been ted.

Area "2" was similarly protected in 1969 but utilizing concrete filled nylon bags. Results are encouraging with no known slides or sloughing. The expense of concrete-nylon bags was less costly than sandstone rip rap. Both types of construction will be closely monitored to establish longevities.

Area "3" is scheduled for protection in 1975 and will be constructed in the same manner as Area "2."

Unfortunately shoreline surveys had not been conducted in the past years to establish rates of erosion. The first indication of a problem was noted in 1967 when slides were observed in the bluff areas 1, 2 , & 3. Protective measures were undertaken to protect against building and utilities damage.

One additional area of structure (Area "4") was damaged by erosions of shale at the millwater filter plant discharge line. A base of sandstone perched on the shale toe was dislodged and was replaced with reinforced concrete in 1974.

Area "5" constitutes a massive sandstone rip rap protection for Hammermill's 1971 Outfall Pipe shoreline facility."

LAWRENCE PARK TOWNSHIP

Beach has a small pier (30 ft.) built in fall of 1972. Beach on west side of pier has built up about 10 ft. but has further been damaged on East side of pier .... Before pier was installed in 1972, beach lost about 10 ft. in depth."

"Vegetation - put in after "cave-in" plus addition of mulch each week during spring, summer, and fall ... (Bluff Recession) 50 ft. by 10 ft."

"(Bluff Recession) Have lost about 4 ft. in center of bluff .... Shale structure at center of lot seems to be weaker than that at edges. The greatest loss of shale and dirt occurred during the spring storm this year."

"Trees on back bluff blown away. Roots caused erosion of soil on bank .... Since 1972, we've had two violent ice storms, which have practically ruined our trees. All lower branches are gone. Back windows and porch ice covered for at least a week and a half. Fish on window sills, back yard covered with fish. Still in back yard from the last storm."

"(Bluff Recession) 50 ft. x 3 ft.... Some vegetation destroyed."

HARBORCREEK TOWNSHIP

"Erosion control attempted several years by vegetation: willow, oats, grass, and 100 plants arnot bristly locust in 1974 .... No beach since 1960 ... (Bluff Recession) 50 ft. x 5 ft.... At top of shale ledge, about 10 trees and 10 ft. x 75 ft. soil eroded."

"(Erosion Control Measures) Railroad ties, heavy logs, trees planted all within last 10 years .... Beach entirely gone because of higher lake level .... Lost 200 to 300 tons of bank ... (Damage to Erosion Control Structures) All gone or washed into lake .... Several large trees washed away."

"From 1973 tree branches, leaves, rye grass, grass clippings distributed over ground that is washing away ... (Bluff Recession) Approximately 40 ft. wide x 5 ft deep .... Shale bank is approximately 7 or 8 ft. above lake level .... When lake gets rough, water rushes up bank and washes ground away into lake. Higher up the bank is clay; ice or snow melting washed a couple trees roots and all, into lake."

"Bank continues to erode and slide every spring, has lost about 20 ft. in 20 years

"(Bluff Recession) 195 ft. wide, 3 ft. each year."

"(Beach Damage) 10 ft. deep lost ... (Bluff Recession) 20 ft. deep .... Steps washed away, plus trees."

"Breakwall built approximately 20 years ago - now completely destroyed .... Two trees lost plus 8 ft. of property."

"A breakwall (pier) was built extending into the lake about 15 ft. in the mid-fifties ... (Beach Damage) There is none left ... (Bluff Recession) Since 1972, a foot or two .... Erosion of bank where pier was attached about 3 ft. .... Trees and bushes along the edge of the bluff have been washed down into the lake .... Most of the damage done to the shoreline was previous to 1972. Within the forty years previous to that we lost a beautiful beach, wooden piers which extended into the lake for docking canoes and row boats. We lost a look-out (a cement block pump-house, and at least 10 ft. of land from 1940 to 1975."

"1933 retaining wall 40 x 15 x 4 ft. front. 60 x 15 x 4 ft. creek side - present condition poor - needs repair partly down ... (Beach Damage) 110 ft. x 30 ft.... Erosion around retaining walls - 3 ft... (Damage to Erosion Control Structures) 3 ft."

"(Bluff Recession) 30 ft. width - 10 ft. deep ... (Damage to Erosion Control Structures) To date, ice and water damage from water spray .... Trees - one oak fell into lake, one undermined, others damaged - broken limbs .... Adjacent property 300 ft. east and 200 ft. west suffered heavy erosion."

"(Beach Damage) Complete ... (Bluff Recession) 10 ft. of shale bluff .... Took out boat launching crane hoist, base and all, including mooring space for boat."

"What used to be a gradual bluff to the beach is now a 30 ft. sheer drop-off. Beach depth is about the same, but some 25 ft. of bluff is gone ... (Bluff Recession) 25 ft. depth loss average, along a 355 ft. width ... 20 to 30 trees have been washed out at shore line and about the last 30 stairs to the beach have washed out."

"About 25 ft. of bluff recession due to lake .... Total loss of dock, boathouses, stairway and three large trees."

"Very little damage (Beach) - trees and bushes cover lake bank ... (Bluff Recession) Very little since we moved here in 1962 .... Since we owned lot from 1952 shoreline has changed some but can still walk down the bank - this year a nice beach."

"Sometime between 1954 and 1960 we had a well dug about 50 ft. down from the top of the bank. In laying a pipe from the house to the well it disturbed the soil on the bank. Then there was a massive landslide. In order to protect the remainder of the bank, we hired a man who put three huge supports at different levels and used many old railroad ties to hold back the dirt. We do not use the well any more but our neighbor does. This was at the east end of our bank. Some years later there was another landslide at the west end of the bluff which took off about two ft. at the top .... Last year the front was torn off a boathouse and this year's storms demolished the whole boathouse built on the beach."

"(Bluff Recession) 500 ft. in width; 1 ft. to 6 ft. in depth .... Stairways lost - several trees - boat - ground covers."

"During past two years, beach has only been existent during calm weather ... (Bluff recession) 30 ft. deep x 30 ft. wide .... Approximately five maple and poplar trees up to 8 inches in diameter washed away."

"High lake level has eroded beach - necessitating construction of reinforced concrete wall for first floor protection; plus the construction of jetties on shore .... Loss of 70 ft. of beach protection (measured from cottage to water's edge of lake) .... Just east of cottage, bluffs have been eroded by high water a distance of over 25 ft., causing trees (some 25" in diameter) to topple into the lake .... The lakeside steel roll-up door for boats was destroyed--finally this opening had to be abandoned, and a protective reinforced concrete wall constructed across the front of cottage .... Due to high level of the lake, the

storms wash stones and gravel into the mouth of Twelve Mile Creek, damming it up, and forming a very sizeable lake, which overflows the property adjacent to the creek. This has flooded the first floor of the cottage to a depth of two feet several times each year."

NORTH EAST TOWNSHIP

"(Beach) completely destroyed ... (Bluff Recession) beach inaccessible."

"(Bluff Recession) lost 20 ft. depth; 100 ft. wide .... Lost about ten black locust trees .... Cliff swallows burrow into bank four feet for nests, which weakens it. I lose more every year."

"Many large trees have fallen and dirt slides have started ... (Bluff Recession) 6-8 ft.; dirt slides have started .... Many trees fell, one of which did $200 damage to well."

"High water has caused most of beach to disappear .... Bluff has been washing out 3 to 6 ft. per year, carrying trees and bushes up to 3 ft. in diameter due to high water in lake and splashing bluff, carrying dirt, etc. out with it. Half of trees and bushes (Bluff) are now gone with cut and undermining of bank .... Has left sheet bluff with no way to get to beach."

"Installation of two 1-1/2 inch plastic pipes at base of bluff to drain springs (1972-1973); condition - good. Disposal of branches, grass, shingles, logs, etc. over bluff to attempt to halt ground sinking at top of bluff (1971 - continuing) condition - fair. Rock fill at top of bluff with retaining wall (1975); currently in progress ... (Beach Damage) Erosion - about 3 ft.... Washout, erosion, sinking at bluff base - 10 ft.... Pipes eroded and clogged. Previous retaining walls overturned .... Top of bluff - front yard eroded 10 ft."

"We are situated near the mouth of Sixteen Mile Creek. While there has been some flooding of property along creek, there has been no permanent damage along our section of beach."

"(Beach Damage) Depth and quantity of sand and gravel loss have been notable since 1972 .... Bluff along east side of building has eroded about 10 ft. since 1972 .... Sand and stones on lake side have washed away, exposing about 6 ft. of patio front since 1972 .... The Sandsuckers, operating close to shoreline have continually removed the natural sand bar, causing waves to break at shoreline, rather than at sand bar."

"Bristly arnot locust plants planted on eroded bluff two years ago (May, 1973). Erosion fairly stable at present time ... (Bluff Recession) 20 ft. wide and 10 ft. deep just above shale bed. Washout. Three trees have been washed out."

"Vegetation gone - concrete gone - trees gone - second pair of steps just about gone .... No beach. It used to be 20 to 30 ft. into the lake; 50 ft. wide. (Bluff Recession) 50 ft. wide; about 10 ft. deep .... At one time, we had up to 30 ft. of beach, now we have none. Every year we lose more cliff and earth. My fence is gone, too."

"Pole, winch, motor for lowering boat cables, cement wall, stairs, platform ... were washed completely from its cement pillars; there was only one guy wire left hanging; everything else is gone into the lake."

"I'm pleased to know at least a "survey" is being made of the damages along this area. We're all concerned over the future of this shoreline. Every major storm whittles away a little bit more away from the bank. I hope this interest doesn't end with just a survey .... Three dozen black locust trees planted on "shelf" area six years ago; also creeping myrtle at top of bank ... (Beach Damage) None - just high water - no beach ... (Bluff Recession) approximately four ft. of recession at top ... (Damage to Erosion Control Structures) everything "wiped out" .... Trees on bank have washed out - no vegetation on bank now. No erosion control existing now."

"(1) Summer, 1972 - pine trees on lower bank; washed away; (2) Fall, 1972, Spring, 1973 - rock fill, washed away; (3) Fall, 1973 - 25 chinese elms; 50-100 lb. chunks of concrete (fill) washed away. (4) Winter, 1973-74 - cut down four (Approximately 50 ft.) trees to fall and lay across washed out sections on bank to act as "catch" for eroding soil from upper bank - washed away."

"Cement breakwall - part was there when property was purchased. About six years ago we extended this. Completely destroyed January, 1972. There is no beach at all - water comes up to where house was .... Breakwall, lawn, trees, house, water and system completely destroyed."

"Boat ramp including winch and winch motor washed out. This was mounted on cement foundation. Stairs washed out - vegetation cover with trees ... (Bluff Recession) 10 ft. depth, 20 ft. long ... stairway and boat dock, three large maple trees washed out .... At present, a block 15 ft. long by 8 ft. high has slid down bluff about 3 ft. and will probably slide down to water during next bad storm."

"112 ft. width; depth of beach has gone from about 100 ft. to 30 ft... (Bluff) erosion extends full 112 ft. width, about 10 ft. depth .... Bottom 15-20 ft. of stairway washed away. Seven to eight large trees washed out with another five/six going."

"Washed a depth of five ft. the whole length of beach. (Bluff) receded a depth of 30 ft. and a width of 100 ft.... Washed everything out on beach; including boathouse .... Damaged steel stairs and destroyed boathouse."

"(Beach Damage) 1973 - the lake came over the top of boathouse as I found fish on top .... Washed bank away and washed my steps and landing which was half-way down .... Floor has fallen in. I had to move my boat and other belongings out."

"Washed away stairway to beach twice (1972-74) .... Washed out roots of tree and it fell across my boat - ruined by boat and tires on my dolly."

"51 ft. concrete breakwall - 4.5 ft. high - undermined 'total failure.' Two ft. collar 3 sides of boathouse - good condition. Approximately 75 ft. clay bank with vegetation cover - some erosion at bottom .... Loss of approximately 60 ft. of beach, exposed shale ... breakwall cracked in two places, erosion behi .... Boathouse doors torn off, some damage to overhanging porch. Front wheels of portable dock torn off .... Little damage until March, 1975 - resulted primarily from lack of shore ice."

"Has cut bank back approximately 7 ft. and changed height from approximately 3-4 ft. to 7-8 ft.... Lost one large tree."

"(Bluff Recession) 4 ft. in depth in the last two months .... Our concrete stairways, two buildings, concrete picnic table, four large trees, the beach (what is left) has been eroded. The bluff or bank has been eroded. The trees that hold the bank are going. If this continues, everything will be gone in the area. I have seen all of this in the last 40 years."

"Retaining wall of patio and boathouse built in approximately 1945. Wall completely eroded away and completely replaced in 1973 at approximately cost of $1,000. Vegetation on bank. Wall shows some cracking from current winter storms .... Today beach is 12 ft. deep; prior to 1972, it was approximately 35 ft.... Little bluff erosion .... Cracks in new retaining wall .... About three trees have fallen in immediate area of beach. Boathouse protected by wall and has so far received no damage .... Retaining wall must be repaired this year to prevent further damage to wall and possible damage to boathouse."

"High water reduced beach width to approximately 15 ft. Waves due to storm washed away 12 to 15 ft. of property and six trees.... Washed away lower tier of steps (12 steps), 4 poplar trees, one willow tree, and one wild cherry."

"High water erosion has washed away about 15 ft. of our bank bluff .... We once could walk down our bank to the beach, but erosion has washed away about 15 ft. of the bank and now we have a 5 ft. drop off to get to the beach .... Erosion caused several trees to be washed out. One large tree falling on several trees to be washed out. One large tree falling on our steps and patio caused extensive damage. Storms have washed away the lower portion of our steps. We don't dare replace them because they will just be washed away again during the next storm due to the high water level in Lake Erie. If a few more feet of our bank get washed away, it will cause our water system to our house to get washed away."

"Planted crown vetch by plant in summer, 1973 - washed away by winter storm erosion .... Trees removed by storms, bank eroded by winter storms .... Larger stones deposited yearly by ice build-up in winter."

"Approximately 8 ft. of bluff has been eroded in past 2-1/2 years .... Lost one large willow tree; one other in danger. Our water is obtained from lake. Water line to lake was washed out, broken, and exposed. Septic leach bed also washed out and exposed; plus loss of tree. Dirt and sand in water line is eroding pump and will have to be replaced ... I would like to know if the water level of Lake Erie was increased at any time to permit the large ore carriers and ocean going ships to navigate in Lake Erie."

"Only 25 ft. of beach remains from a previous 150 ft.... All sewer systems washed out."

"Railroad tie wall 9 ft. high built in 1965. It's in good condition ... (Beach Damage) 50 ft. long x 10 ft. wide pile of flat rocks ... (Bluff Recession) 3 ft. wide x 4 ft. deep."

"Breakwall - construction 1972 - 1974 - good condition .... Beach of 75 ft. has eroded .... Breakwall partially washed out in 1972 & 74 .... Boat ramp destroyed, has uprooted; landscape damage."

"Had a breakwall made out of brick and stone 239.5 ft. length of beach, water was 55 ft. from breakwall area, there is no more breakwall - washed out by waves, due to high water in Lake Erie ... (Beach Damage) 238.5 x 50 ft. Lost 11,975 sq. ft. of land from high water .... Lost water system three years in a row. Sewer systems also three years in a row. Lost 5 large oaks, 6 locust trees, 14 evergreen trees, 239.5 ft. of stone breakwall, 7,185 sq. ft. of grass, power winch, light system, and dock."

"No damage in last three years, but the high level of water has caused considerable trouble due to debris, sand, rock, etc. which had to be removed from pier, patio, etc."

"Reinforced concrete breakwall built in 1955. Good condition. Has withstood all storms so far .... At this location for 24 years. Beach depth changes each storm and year according to lake level. Too many (other) places built along the lake without considering lake level history."

"(Bluff Recession) Base of bluff approximately 10 ft. in depth .... A number of years ago there were two cottages on the beach, which were completely destroyed by high water in the spring. A factor to consider here, was the base construction of the cottages was poor; but now, in 1975, no cottage could withstand the pointing of the high water during the winter and spring months, in that particular location. We have erected a bathhouse on top of the bluff, because we know there would be no chance of it surviving down on the beach. Our property fluctuates between no beach at all during the high winter water level to about 30 ft. of beach during the summer, providing there has not been too many storms out of the northeast. A northeast storm washes all the beach away from our property."

APPENDIX E

CONTROL POINTS

CONTROL POINT INFORMATION

The recession rate analysis, computed from aerial imagery using topographic maps as a basis for scaled distance, provides a relative initial measurement. It is apparent that the ground distances computed must necessarily contain inaccuracies inherent in the topographic coverage. Accurate ground distances for survey purposes are outside the capabilities of such maps. Thus, it must be understood that the recession analysis is based on the distance difference between various sets of imagery utilized. These relative distances are accurate because of the care taken in scale conversion.

If actual distance with established survey accuracy is to be known, it is essential that control points be established in critical hazard areas and measured by transit or chain. A number of such points have been established and measured and represented on maps contained in the report. This Appendix gives the precise location of each point so that they can be found for future measurement for purposes of establishing a recession rate from actual ground truth.

The points have been established to represent the variety of coastal conditions that exist. The focus, however, has been on critical areas where recession is accelerated and where there is imminent danger of loss of property and/or structures.

CONTROL POINTS

LOCATIONS AND MEASUREMENTS

Site Number	Location and Physiographic Information	Distance
1.	Ohio State Line - Springfield Township From the center of Lake Road on a line north along the western edge of the third cottage east of the State line to the bluff The bluff at this location is extremely active and devoid of vegetation.	270.0 feet
2.	Rudd Road - Springfield Township From the center of the intersection of Rudd Road and Lake Road north to the bluff on a line along the center of Rudd Road. Rudd Road was until recently used as a boat access area. Recent rapid recession has left the end of the road elevated and the boat access inoperative.	340.0 feet
3.	Eagley Road - Springfield Township From a utility pole number 32672 in the parking lot of Eagley Beach Park on a line north to the Beach backshore.	198.0 feet
4. & 5.	Holliday Road - Springfield Township From a marker 15 feet east of the center of Holliday Road and approximately 10 feet from high water level to bluff edge.	4.5 feet
	From the bluff, through the above marker south to the gate post on the north side of the Holliday Shores access road. The bluff in this location is rapidly receding; evidence of 5-10 feet over past five months; several cottages in danger on a low bluff.	89.0 feet
6.	Camp Sequoyah - Springfield Township From the northwest corner of a building now named McBrier Lodge north on a line to the edge of the bluff.	53.0 feet

Site Number	Location and Physiographic Information	Distance
	A high bluff, there is evidence of only moderate recession save for the area directly in front of the lodge where disrupted vegetation is an indication of recent continuing activity.	
7.	Elk Creek - Girard Township From a utility pole No. 32222 which is 100 yards east along the service drive for the cottages east of Elk Creek, north on a line to the bluff.	58.2 feet
8.	Lake Erie Community Park - Girard Township From the pavilion now designated as Number One, the northwest corner north on a line to the bluff. A high bluff, activity recent in the form of slumping with disruption of vegetation.	87.0 feet
9.	Godfrey Run - Girard Township From the northwest corner of the deck of a dwelling now occupied by Evans north on a line to the bluff. Recent activity on this bluff due to recent construction of residence and ensuing landscaping.	80.0 feet
10.	Melhorn Road - Fairview Township From the northeast corner of a dwelling at 7950 West Palmer Drive now occupied by C. E. Palmer north on a line to the bluff. The bluff here is stable with a complete vegetative cover.	157.0 feet
11.	Lake Shore Drive - Fairview Township Opposite the driveway of a dwelling at 6009 Lake Shore Drive now occupied by Charles Metzgar, the center of the road north on a line to a water intake structure location on the bluff edge. The bluff is stable with vegetation cover but proximity of the bluff to road makes this an area for concern.	25.0 feet

Number	Physiographic Information	Distance
12.	Glenruadh Avenue - Millcreek Township From a utility pole No. B13701 at the foot of Strathmore Avenue north on a line to the stairway balcony to the beach, to the bluff edge. A stable bluff, however, there is some concern due to dense residential pattern, both on the top and bottom of the bluff.	70.0 feet
13.	Lakeside Drive - Lawrence Park Township On a line along the western edge of the property at 2664 Lakeside Drive, now occupied by Gerald Porter from a utility pole No. J-112 northerly to the bluff edge.	146.0 feet
14.	Lawrence Park Golf Club - Lawrence Park Township At the foot of the Club access road in the parking lot, a utility pole northerly to the bluff edge. The bluff exhibits recent recession with vegetative disruption at the crest. The base of the bluff is protected by bedrock to 20 feet, recession taking place over the bedrock section.	72.5 feet
15.	Taylor Avenue, Fairfield - Harborcreek Township At the foot of Taylor Avenue, a fenced pumping station; a utility pole at the rear of the fenced area northerly on a line to the bluff. Some recent recession of bluff noted above bedrock section.	67.0 feet
16.	Cowell's Beach - Harborcreek Township The third cottage east of the groin at Cowell's Beach; from the gas company valve north on a line separating the property of the third and fourth structure, to the bluff.	67.0 feet
17.	East Drive - Harborcreek Township On a line marking the east boundary of 7824 East Lake Road, a dwelling now occupied by Mark Ripley from the center of the road to the bluff. The bluff is relatively stable with little apparent recession. Base has bedrock protection and moderate beach.	172.0 feet

Site Number	Location and Physiographic Information	Distance
18.	Shorewood Inn - Harborcreek Township On a line northerly from the northeast corner of the Shorewood Inn to the high water mark, inside a steel drum breakwall. This distance will be variable with lake level and conditions, but future monitoring should reveal loss of beach.	83.0 feet
19.	Catholic Cemetery Road - North East Township West of the intersection of Cemetery Road and East Lake Road a utility pole No. B13479 at the entrance to a residence now occupied by Richard DeVore; northerly on a line to the bluff. Bluff is stable with vegetation present. Deep incisions due to past slumping activity and drainage diversion.	123.0 feet
20.	Cemetery Road - North East Township On East Lake Road from the road marker post 7-35 on a line northerly to the bluff.	147.0 feet
21.	Woodmere - North East Township From the northwest corner of the second cottage east of the mouth of Perdue Run, now occupied by Carl Dailey, northerly to the edge of the bluff. A low bluff consisting mostly of sands and clays formerly protected by extensive beach now essentially destroyed.	23.5 feet
22.	Dewey Road Fish Commission Access Area North East Township From a utility pole No. 1273 in the access area northerly on a line through the cement ramp to the water's edge. Measurement is variable with lake level and conditions. When measured, conditions were calm with no wave activity.	104.0 feet
23.	Gay Road - North East Township Along the east boundary of 82 Gay Road, northerly on a line from the center of the road to the beach backshore. The beach backshore at this location on this day was immediately in front of 82 Gay Road.	82.0 feet

APPENDIX F

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